CHAPTER I
INTRODUCTION

1.1 Definitions of Creativity

There are many definitions available in literature for the term ‘Creativity’. Those who emphasize the outputs of creative effort, describe creativity as the discovery of something that is novel but also useful or relevant or economical or elegant or valuable. According to Don Mackinnon (1962), ‘mere novelty of a product does not, however, justify its being called creative; additionally, the product must be adaptive to reality’. A fluid requirement is that the creative product must be developed or produced. Two other desirable conditions of Mackinnon are that the product is aesthetically pleasing and significantly changes our view of the world.

In accordance with another viewpoint, ‘Creativity’ is divergent thinking: the seeking of relationships between previously unrelated concepts or frames of reference and exploring the unknown. The outcome of this effort may or may not be creative, but the effort reveals that the characteristics of a creative process; wide search or exploration, leaps of imagination, incubation, and sometimes strikingly fresh insights.

Thus we may conclude that Science and Art may generally be considered as more creative pursuits than factory or industry oriented manufacturing pursuits. The former exhibits more divergent thinking than the problem solving related factory work.

Still others identify ‘Creativity’ with certain states of being. For example, Abraham Maslow (1954), the prominent psychologist, has identified ‘Creativity’ with openness in expressing feelings, receptivity to ideas, and concern for others, desire to grow as a person and actualize one’s potential, and so forth. Other psychologists have compared creative and non-creative persons from the same profession. They have identified a number of additional personality traits and abilities that distinguish
creative from non-creative persons. The ability to come up with many and varied and uncommon ideas or solutions also seems to distinguish creative from non-creative persons in addition to their ability to notice anomalies, issues, paradoxes etc.

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Next chapter elaborates the literature on general ‘Creativity’ of the psychological term and also on the ‘Creative ability’, which is more logically expressible.

1.2 Creativity Vs Intelligence

Each one of the above views of creativity may be defective, if one judges creativity only in terms of the novelty and usefulness or elegance with respect of a product. One may sometimes find that the creative product may have been discovered or produced either accidentally or through a non-creative process. Today, innovations are increasingly institutionalized. For example, many researchers discover something or the other simply by taking a problem area and by applying it through a scientific method. Indeed, Abraham Maslow has contemptuously disposed off universities and scientific establishments as havens of the mediocre.

‘Creativity’ comes in many forms and types. The skills needed to practice each of these types of ‘Creativity’ may differ substantially. If a creative representation is considered, it requires intimate knowledge of whatever is sought after and also a freshness of perspective.
‘Creativity’ is a mental ability, which is distinguished from intelligence as the later is measured in contemporary IQ tests. The best way to appreciate the difference between creativity and intelligence is to do a test on each one. Given below is a 5-minute “test”, that will show a difference between intelligence and ‘Creativity’.

The TEST

1. Find the word that does not fit with the rest.

MBAOBY DNOONL COWSOM ATR

2. Guess the word given the following four clues:

Law Chair Bangle Sword

3. Write the 3-letter word that means the same as the words outside the brackets.

PROHIBIT (___ ___ ___) DRINKING PLACE

4. Complete the following sentence humorously:

One moonlit night, while strolling in a garden,

5. Find the missing number:

<table>
<thead>
<tr>
<th>2</th>
<th>9</th>
<th>0</th>
<th>8</th>
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<tbody>
<tr>
<td>4</td>
<td>10</td>
<td>5</td>
<td>-4</td>
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<tr>
<td>3</td>
<td>5</td>
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<tr>
<td>3</td>
<td>14</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

6. Give some striking alternative titles to World War II.

It may be noticed that possible solutions are much fewer in the three IQ items, 1,3 and 5; to solve them mostly logic and vocabulary rather than imagination are required; and that solution once found fit the problems rather snugly. In the creativity
items, a number of other mental capabilities get exercised, such as associative thinking as in item 2, wide search as in item 4, and an enormous degree of compression of thought required in item 6 that must, however, be expressed aesthetically. With that there is no certainty at all that the solutions are the best possible or even good. As is obvious, the degree of convergent thinking needed is much higher for the IQ problems than for the creativity problems, while the degree of divergent thinking needed is much higher for tackling creativity as compared to IQ problems. They represent quite distinctive sets of abilities, and indeed, research suggests that those who are high IQ scorers are not necessarily creative and vice versa (Frank Barron, 1969).

1.3 Determinants of Creativity

Scholars of 'Creativity' have suggested a number of determinants of creative behaviour: the person's biological constitution and genetic inheritance; his or her personality; the nature of the organization or institution with which the person is affiliated; the orientation of the group or team in which the person is a member; the nature of the work the person does; the values and practices of the culture in which the person belongs to and so on. Genetics and environment may affect facts of 'Creativity', such as fluency, flexibility, originality, elaboration ability etc. in different proportions.

Besides, heredity, environment, and motivation, it is found from literature that certain physiological states seem to be associated with 'Creativity'. There is indication that creative ideas are more likely to occur during the theta brain wave rhythm than the alpha or the beta rhythm. The theta rhythm is generally induced in a state neither of excessive excitation nor of excessive relaxation. It is induced in a state of relaxed alertness. Transcendental meditation seems to lower anxiety levels and creates a state of relaxed alertness. Research indicates that the practice of Transcendental meditation increases both convergent thinking ability (intelligence) and divergent thinking ability (especially fluency). Mild stimulants or stimulating
problems, and lowered defensiveness and anxiety, may also induce this state of relaxed alertness.

1.4 Creativity and Scientific Inventions

Inventor: By assuming this role, Engineers recognize the need for developing new inventions, devices or appliances and venture into developing them either as an individual scientist or by taking part in a dynamic and dedicated team. By developing new inventions, engineers play the role of milestones in the evolution of human civilization. Internationally reputed Scientists like Albert Einstein, Neils Bohr, Thomas Alva Edison, Rutherford, Sir C.V.Raman, Subramaniam Chandrasekhar, Marie Curie, Srinivasa Ramanujan, Michael Faraday have been quite successful scientists primarily due to their skillful application of Creativity for the specific purposes they had in mind. Most of these Scientists had only a very humble beginning and were confident enough in proving their capacity with the limited resources they had, for their enterprising accomplishments.

1.5 Creative Leadership

Leader: Engineers have the potential to play the vital role by assuming the effective role of Leadership at various levels such as Project Managers/Leaders, Managing Directors, Chief Executive Officers, Corporate Leaders etc., To be a very successful leader, one has to be very ‘Creative’ in developing a viable and realistic vision and mission of the Organization, by developing viable plans to achieve them and in executing them successfully and continuously.

To play the effective and efficient Leadership role, a leader has to be very creative in developing an appropriate Vision and suitable strategies as Mission for achieving the goal. In addition to it, a Leader has to have a team of creatively gifted persons, in order to translate the creative ideas into reality.
Classical examples of having such eminent leadership are Bill Gates of Microsoft, Mustafa Kamal of Turkey, John F. Kennedy of U.S.A., Lee Kuan Yew of Singapore, Jawaharlal Nehru and Mahatma Gandhi from India.

It is quite noteworthy that an Engineer, irrespective of the discipline, has to be very creative for leading a successful life in any one of the combinations of the three roles of Inventors or Entrepreneurs or Corporate Leaders. This adduces the importance of incorporating ‘Creativity’ as an important component in the Curriculum of Engineering Education, especially at the undergraduate level.

1.6 Creative Thinking and Computers

Although computers may be considered superior to human beings in many aspects like memory capacity, data or information retrieval speed, processing speed of arithmetic manipulations, accuracy of results in logical manipulations etc., computers cannot perform ‘Creative thinking’. They can, at the most, be used as excellent tools in stimulating the ‘Creative’ thinking part of human mind. Computers are devoid of the capacity of generating original ideas on their own.

In pedagogical terms, a learner’s competencies can be listed as follows, in the ascending order of the importance of mental skill levels:

1. MEMORIZING
2. KNOWLEDGE
3. UNDERSTANDING (COMPREHENSION)
4. ABILITY TO APPLY KNOWLEDGE
5. ANALYSIS
6. SYNTHESIS
7. EVALUATION
8. PROBLEM SOLVING ABILITY
9. EFFECTIVE COMMUNICATION or ELABORATION
10. CREATIVITY or CREATIVE THINKING
Among all these competencies, computers (which were developed as functional substitutes for human brain) may be capable of doing all the above categories to some or other extent, but not the last one viz., ‘Creative’ thinking, as this may not be categorized into any logical form as such.

But it is noteworthy through published works, that accomplishments in areas such as painting, poetry, literature, architecture and fine arts, ‘Creativity’ plays a major role. Apart from these areas, great inventions and discoveries in Science and Technology too, are still exclusively, due to the factor of ‘Creative’ thinking only. Literature also shows that, this ‘Creativity’ in Science and Technology may be more specifically termed as ‘Creative ability’ rather than ‘Creativity’ of the general psychological term. This may be due to the fact that, ‘Creative ability’ may be more categorized in logical terms.

Alan Turing, the pioneering Scientist in the realms of Artificial intelligence and the renowned British mathematician has proposed a test known as ‘Turing’s Test’. This test was published in his paper ‘Computing machinery and Intelligence’ (Alan Turing, 1950) in ‘MIND’. Turing primarily known for his contributions to the theory of computability, considered the question of whether a sophisticated computer that could be available in future, would be able to succeed the best possible human mind in all its capacities.

From the functional viewpoint, human thinking can broadly be classified into the following four types:

1. **Absorptive Thinking**: The ability to apply attention and to absorb ideas or concepts.

2. **Retentive Thinking**: The ability to retain whatever that was understood and to recall, as and when it is required.

3. **Reasoning Thinking**: The ability to apply reasoning and to take logical decisions in the given contexts or situations.
4. **Creative Thinking:** The ability to foresee, to visualize and to generate ideas in a given situation or context.

As of now, with the most sophisticated computers that are available today, Computers are capable of performing the first three types of thinking, to some or other extent, but definitely not the fourth type of thinking viz., Creative thinking. So, ‘Turing’s Test’ is very helpful in checking whether the computer is capable of surpassing human mind in all its capabilities i.e., inclusive of applying creative thinking.

The ‘Turing’s Test’ { George F. Luger (2002) } measures the performance of an allegedly intelligent computer against that of a human being, arguably the best and only standard behaviour, both in terms of performing intelligence and creativity.

‘Turing’s Test’ which is also called as the ‘Imitation game’, places the computer and the human counterpart in isolated rooms apart from a second human being referred to as the ‘Interrogator’. The Interrogator can not see, speak or interact directly to either to the Computer or the other human being, the only exception being the allowance for communicating with either one of them, through a tele-typing textual device such as a terminal. The ‘Interrogator’ is asked to distinguish the computer from the human being solely on the basis of their answers to questions asked over the tele-typing device. If the interrogator fails to make a proper identification of the Computer through its answers, then, Turing argues that the computer can be claimed to have surpassed the human mind in all its capabilities.

By isolating the interrogator both from the computer and the other human participant, the test ensures that the interrogator would not be biased by the appearance of the computer or any mechanical property of its voice. The interrogator is free, however, to ask any number or quality of questions, no matter how deviating or indirect they are, to uncover the computer's identity. For example, the interrogator may ask both subjects to perform a rather involved arithmetic calculation, assuming
that the computer would be more likely to get it correct than that of human's; to
counter this strategy, the computer would need to know, when it should fail to get a
correct answer to such problems in order to provide apparently human answers. To
discover the human identity on the basis of emotional nature, the interrogator may
ask both the subjects to respond to a poem or work of art or anything that might be
emotionally appealing to humans; this strategy would require that the computer have
knowledge concerning the emotional makeup of human beings.

The important features of the 'Turing's Test' are:

1. It provides an objective notion of intelligence. i.e., the behaviour of a known
   intelligent being in response to a particular set of questions. This provides a
   standard for determining intelligence that avoids the inevitable debate over its
   'true' nature.

2. It prevents one from being sidetracked by such confusing and currently
   unanswerable questions as whether or not the computer uses the appropriate
   internal processes or whether or not the computer is actually conscious of its
   actions.

3. It eliminates any bias in favour of living organisms by forcing the interrogator,
   to focus solely on the content of the answers to questions.

4. As of now, the Computer is far away from succeeding in 'Turing's Test' due to
   the following reasons:

   (i) The presently available computers, however sophisticated they
   are, do not have 'the capacity of imagination', which is considered
   to be the raw material for 'human creativity' and is regarded as the
   pristine capacity of humans for the remarkable advancement of
civilization over so many centuries.
(ii) The presently available computers are capable of dealing with ‘Natural Language Processing’ to a very limited extent; accordingly, they are unable to communicate with the human beings in their languages of communication.

(iii) Computers do not have emotions, due to which, they do not have the ‘weakness of flesh’, which is the primary reason for the unpredictability of human behaviour.

(iv) Computers, bye and large, are not autonomous; In other words, they have to depend upon the humans for being given proper instructions though Computer programs; if not programmed, they would find it very difficult to act on their own, especially in a complicated context or environment.

(v) Computers are free from emotions, due to which, their day-to-day functional routines are totally different.

(vi) Computers are either faithful or otherwise (due to malfunctioning or improper ambience); but never a combination of both. So, computers are always loyal and never disloyal, unlike human beings, who are a combination of both.

1.7 Creativity in Education

In our present system of education, students receive so much spoon-feeding in terms of how-to-do-it instructions-in school, at home and at work due to which, most of them lack almost any opportunity for displaying creativity or for being creative. If this is so, it may lead to a society of ‘sick’ people. Abraham H. Maslow (1954) postulates that a person who does not have a basic need fulfilled, is sick, just as a man is sick, who lacks vitamins and minerals. The five basic needs to which Maslow refers are (i) Physiological needs (ii) safety needs (iii) love, affection and belongingness needs (iv) esteem needs (v) need for self-actualization.
Maslow emphasizes that the need for self-actualization is a healthy man’s prime motivation. Self-actualization means actualizing one’s potential, becoming everything one is capable of becoming. Maslow says: ‘What a man can be, he must be’. Education can help in providing this need by building the environmental turnpikes on which the individual may drive, once he has removed the mental governors that restrict his creative ability.

Education can help provide the ‘psychological safety’ and ‘psychological freedom’ necessary to the creative individual. This need not mean license for needless non-conformity. But it does mean complete freedom for non-conformity of thought, even if not for non-conformity in behaviour. In other words, the creed of a creative individual must be as: ‘Give me the courage to change those things that can and should be changed, the strength to accept those things that cannot be changed and the wisdom to distinguish between the two’.

In the current generation of bewilderingly rapid changes, nuclear, space, information technological innovations happen much faster than ever before. The discoveries, inventions and innovations of the next twenty years, will probably make the previous hundred years, seem to have progressed at a snail’s pace. Therefore, a person cannot foresee exactly what knowledge, he will need for five or ten years from now to meet with his professional or life’s problems. He can, however, develop the attitudes and abilities that would help him in meeting with any future problem creatively and practically. Education pursued at any level, should help for attaining this objective. Otherwise, the purpose of acquiring ‘Education’ is not at all served totally.

If we explore an interesting study on the research done by two psychologists Getzels and Jackson (Getzels & Jackson, 1962), it will throw light on the pathetic plight of highly creative students in the classroom environment. They studied two contrasting groups of children in a highbrow Chicago school. One group was high on I.Q but relatively low on creativity, while the other was high on ‘creativity’ but relatively low on I.Q. The fascinating finding was that the students with high I.Q.
were, more conformists in a special sense. In their responses to problems, they were more bound by a stimulus, by the constraints in a problem situation. The highly creative students did not find the ‘given assumptions’ as binding, and as a consequence they were more playful and explorative in their responses. For example, when asked to paint a picture on a white drawing paper, a highly creative child did nothing except providing a title to the blank page, and the title thus given was ‘The school yard during a snowstorm’. When asked to mention the careers they planned to pursue, the highly intelligent students commonly listed the typical American middle class high status professions such as medicine, law, University Professor etc., There were much greater variety in the career choices of highly creative students, and many of them preferred quite off-beat careers such as adventurer, inventor, writer etc., As Getzels and Jackson wrote it, in effect the highly intelligent student says, ‘I know what makes for success and what teachers like and I want these qualities too’; the highly creative students say, “I know as well as the high IQ student, what makes for conventional success and what teachers like; but these are not necessarily the qualities, I want for myself”. To summarize, the highly intelligent students were apparently more risk-aversive and while answering the test questions, gave more or less safe answers. For example, take these two responses, to a picture showing an adult sitting in an airplane.

**Response number one was**

Mr. Smith is on his way home from a successful business trip. He happily thinks about his wonderful family and how glad it would be to see them again. He can have a mental picture about what would happen after an hour from now, his plane leading at the airport and Mrs. Smith and their children are all waiting there, to welcome him, at home.

**Response number two was**

This man is flying back from Reno, where he has just won divorce from his wife. He could not stand to live with her anymore, he told the judge, because she
wore so much cold cream on her face at night that her head would skid across the pillow and hit him in the head. He is, now, contemplating a new skid-proof face cream.

One significance of Getzel and Jackson’s work was that they found teachers preferring the highly intelligent students to highly creative students, even when grade-wise both had performed equally well. And that too in U.S.A. in a private high brow school!

The highly creative student, with his moodiness, unpredictability, penchant for humour, his regular habit of questioning the basic premises and so forth, is often a menace to the ordinary teacher; while the highly intelligent, but not so creative child, bright and eager to please the teacher, with his habit of repeating the ideas of the teacher or those found in the prescribed textbook, tends to become the teacher’s pet. This situation helps in understanding the monumental tragedy of the educational system that prevails in different parts of the world, especially so in technologically and economically advanced countries. To begin with, most of the ‘Entrance tests’ or ‘University Examinations’ predominantly assess memory and convergent thinking abilities. The selection of the top 20% in I.Q. may eliminate 70% of the top 20% in creative thinking (J.P. Guilford, 1968) Most of the teachers, further discourage divergent thinking in the classroom. No wonder that those who are appreciated and acknowledged as the best students in the academic environment, fail often miserably to accomplish anything original or outstanding in life, and quite commonly the so called difficult or mediocre student, with an overall mediocre record, but brilliant performance in topics of interest to him, blossoms out in life. Here it is noteworthy that Newton and Einstein were considered as dullards at their respective schools. It is left for the globally renowned Educationists and Psychologists to speculate on the cultural consequences of thousands of years of total or major discouragement of creativity and divergent thinking in our so called reputed schools, Universities or any other such academic institutions and thus a blockade for advancement in civilization..
1.7.1 Creative abilities

It is found from literature that 'Creativity' is not confined to one ability alone, but a whole cluster of abilities (Pradip N. Khandwalla, 1992). The most important of these abilities are as described below:

1. FLUENCY OF IDEAS

Fluency is the ability to come up with a large number of ideas or solutions to a given problem. Fluency works primarily through the process of associative thinking. One idea leads to another, second idea to a third one and so on. Fluency can be improved by trying to get answers for questions like 'How would you make your students to be more interested in 'Computer Graphics'?' etc.

2. FLEXIBILITY

It is the ability to come up with a variety of ideas or concepts to a given problem. For example, to answer the question, 'What are the uses of bricks?' One can tell us (i) Used as a construction material or (ii) as a weapon to attack, instead of telling as used for building bridges or houses etc.

3. ORIGINALITY

It is the ability to come up with unusual but appropriate responses. For example, Use of brick (i) as a substitute for pillow (ii) as a hiding place for jewellery and so on. Originality is the vital element of 'Creativity'. Try to get answers for questions like, 'suppose that your child has no gift for music, but loves it. How would you help him/her to become a good Musician?'

4. GUESSING ABILITY

It is the ability to go to the roots of a phenomenon by unraveling its causes. It makes good guesses about the causes and consequences. This is considered to be a vital ingredient of Scientific Creativity.
5. SENSITIVITY

It is the ability to spot the uncommon; to be sensitive to feelings, sight, smell, sound, etc., Try to get answers for questions like ‘Why some experts in designing efficient algorithms have aversion to working with computer terminals?’

6. ELABORATING ABILITY

It is the ability in a particular theme. It involves working out with the implications of a bright idea by a combination of analytical, evaluative, and associative thinking. Try to get answers for questions like (i) Elaborate upon the paradoxical proverbs “Stitch in time saves nine’ or ‘Haste makes waste’.

The presence of all these abilities facilitates ‘Creative ability’, which is distinguished from ‘Creativity’ of the psychological term. The term ‘Creativity’ is synonymously used in the place of ‘Creative ability’ throughout this research work.

1.8 Vertical Thinking Vs Lateral Thinking

Lateral thinking and vertical thinking are complementary in nature and are not antagonistic. Lateral thinking is useful for generating ideas and approaches, while vertical thinking is useful for developing them. Lateral thinking enhances the effectiveness of vertical thinking, by offering it more to select from. Vertical thinking multiplies the effectiveness of lateral thinking, by effective use of ideas generated, by the former. Even though vertical thinking is frequently used, necessity often arises to apply lateral thinking, in which case, excellence in vertical thinking will not be of any use. When there is a compulsory situation to use lateral thinking, it is dangerous to use vertical thinking. To be successful in Engineering profession, Engineering students have to consciously nurture both of these thinking skills. The differences between vertical thinking and lateral thinking are listed out in table 1.1
<table>
<thead>
<tr>
<th>S.No.</th>
<th>VERTICAL THINKING</th>
<th>LATERAL THINKING</th>
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<tbody>
<tr>
<td></td>
<td>Being correct matters</td>
<td>Being rich matters</td>
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<tr>
<td></td>
<td>Selects a pathway by executing other pathways</td>
<td>Seeks to open up other pathways</td>
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<td></td>
<td>When provoked, it promotes to select the most promising approach to a problem</td>
<td>When provoked, it generates as many alternative approaches as possible</td>
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<td></td>
<td>It moves only if there is a direction in which it has to move.</td>
<td>It moves in order to generate a direction</td>
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<tr>
<td></td>
<td>It is analytical</td>
<td>It is provocative</td>
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<td></td>
<td>It is sequential</td>
<td>It can make quick jumps</td>
</tr>
<tr>
<td></td>
<td>While applying, one has to be correct at every step</td>
<td>While applying, one need not be correct at every step</td>
</tr>
<tr>
<td></td>
<td>With it, one uses the negative in order to block off certain pathways</td>
<td>With it, there is no negative feature.</td>
</tr>
<tr>
<td></td>
<td>With it, one concentrates and excludes what is irrelevant.</td>
<td>With it, chance intrusions are appreciated.</td>
</tr>
<tr>
<td>10</td>
<td>With it, classifications and labels are fixed</td>
<td>With it, classifications and labels are NOT fixed</td>
</tr>
<tr>
<td>11</td>
<td>It follows most likely paths</td>
<td>It explores the least likely paths</td>
</tr>
<tr>
<td>12</td>
<td>It is a finite process</td>
<td>It is a probabilistic process</td>
</tr>
<tr>
<td>13</td>
<td>With vertical thinking, we use information for its own sake, in order to move forward to a solution</td>
<td>With lateral thinking, we use information not for its own sake, but provocatively in order to bring about restructuring or re-patterning</td>
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This table clearly shows that lateral thinking is as important as vertical thinking and so it is essential for the engineering students as well as professionals to get trained in both of them.

1.9 Creativity in Engineering

Graduate students of Engineering may be expected to play the roles of the following personalities:

Engineering as a discipline, falls under the category of Science and Technology, at least in the Indian context. According to literature, only if engineers know that creativity is a valuable tool, they will be able to learn using it effectively and applying it resourcefully.

Creative Intelligence consists of alternate phases of Convergent and Divergent thinking abilities. Unfortunately very little is known about the order in which these abilities are marshaled. It is axiomatic that the order would vary both by the nature of the problem and the skills and habits of the problem solver. This is much more relevant in Engineering. For instance, in every engineering design solution, the analysis is almost unique, whereas several acceptable design solutions are possible. Fig. 1.1 shows a simplistic model of how convergent thinking and various divergent thinking abilities can be collectively utilized.

This model highlights two significant aspects of creative Intelligence. The first is the variety of natural abilities needed for intelligence to bear creative fruits. The second is that, if any of the abilities in Fig. 1.1 is especially weak, the flow of ‘Creativity’ may be seriously affected. For a person to be very creative, exceptional talent in one or two abilities may be of less advantage than at least moderate strength in all of them.
Certain abilities and stages noted in this model indicate that training would play a vital role and may help in improving the individual abilities and thus the overall process of ‘Creativity’. Hence, technology - enhanced teaching / training would certainly improve ‘Creativity’ in Engineering.

1.10 Creativity in Engineering Education

To be extremely intelligent need not be extremely ‘Creative’. Students with high intelligence need not necessarily be the ones, who produce the most original ideas. In the classroom environment almost all the teachers are interested in evaluating a student’s intelligence and not his capacity to think creatively. In accordance with the scientific tests conducted to find out creative aptitude, there is little or no difference found between college and non - college students of similar ages. It is also found that education is not a vital factor in the process of producing creative ideas. Many highly trained or educated persons may be creatively sterile, while some others accomplish outstanding results in the areas of their pursuit in spite of almost totally lacking formal education.

It is also found that those, who were devoid of specialized training in specific problems involved, have generated many great ideas. Morse, a professional painter of portraits, developed telegraph. The steamboat was devised by Futon, an artist by profession. Eth Whitney, a school teacher, devised the cotton gin.

Psychologists and educational experts assert that creativity includes the following phases as generally accepted.

Orientation: Focusing the problem in such a way that complete details about the problem to be solved are known.

Preparation: Collecting relevant data from all possible sources that will help in finding out all appropriate solutions to the chosen problem.
Analysis: Breaking down the relevant materials collected and asserting them in such a way that one or more methods can be devised to find out a suitable solution.

Ideation: finding out as many methods as possible in finding out an appropriate solution for the chosen problem. While developing such methods one should not have any reservation about the practicability or feasibility of the method considered. Sometimes others may scoff at a brilliant idea owing to the apparent difficulties encountered in considering them.

Incubation: This process leads to let up and to anticipate illuminations. The problems, which are considered to be extremely difficult or impossible to solve, may be studied seriously. If the person who wants to find a solution for the apparently impossible problem, while concentrating on some other work may subconsciously be actively involved in finding out a solution by applying creative thinking. This is known as Incubation.

Synthesis: After the problem being fed into the subconscious mind with all relevant details of the problem, after having analyzed the various strategies developed, all the relevant items of information have to be assembled together in such a way that appropriate combinations are assorted and synthesized properly.

Evaluation: This is the phase during which the resultant ideas, which were derived from the previous phases, can be summarized and evaluated for the practicality and feasibility of the solutions obtained and the best possible solutions can be considered for implementation.

All the above phases involve logical steps and hence as stated in the beginning, that 'Creative ability' can be brought under logical framework.
Figure 1.1

A MODEL OF CREATIVE INTELLIGENCE IN TECHNOLOGY:

IDENTIFICATION OF PROBLEM
(Ability to sense the odd or anomalous)

ENGINEERING ANALYSIS
(Sensing of problems, issues, opportunities etc.,)

CONVERGENT THINKING ABILITY, CAUSES GUESSING ABILITY
(Trial Design with Initial data) *

STRUCTURING PROBLEMS * (Mathematical Models)

PROBLEM RESTRUCTURING ABILITY (Redesign)

REANALYZE & REDESIGN
(A new understanding of the problem that facilitates interesting new approaches, Divergent thinking, search for Alternative Approaches, and Solutions)

FLUENCY
(ability to generate many responses to the given problem)

FLEXIBILITY *
(ability to generate a variety of responses to the given problem)

ORIGINALITY
(Recommended Design)
(ability to come up with novel, unique, yet appropriate solutions)

Evaluation Through Convergent Thinking

Consequence of Guessing Ability

Elaboration of idea, Approach or Solution

Refinement through Convergent Thinking Ability

* The stages during which training may play a vital role in acquiring proficiency.
1.11 Techniques of Creative Thinking

The following suggestive measures can be applied for an exhaustive list of techniques of creative problem solving.

**Brainstorming:** It can be done either by a group of persons or by individuals. It has also been found through research that when individuals do brainstorming, they tend to outperform a group consisting of equal number of individuals both in terms of the quantity of ideas and their quality.

**Attribute Listing:** In attribute listing, an attempt 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 generate alternatives to the current attributes or specifications.

**Synectics:** It is a remarkable technique of group problem solving and to a novice it looks like a mad method for finding solutions. But it is found to be more practical, as testified by the clientele of Synectics Inc., which include Colgate-Palmolive, Kimberley Clark, Singer Manufacturing, Western Electric, Johnson & Johnson, General Electric, IBM, Union Carbide, Monsanto and other leading US corporations. Synectics is a group technique and it thrives on the diversity of constituent members of the group.

**Checklists of Questions:** To have an innovative society, the habit of questioning everything is indispensable. Questions are the creative acts of intelligence as they energize divergent thinking. So, checklists can be used to generate ideas, especially for identifying new product ideas by making alterations to existing products (Taylor, 1961). A typical checklist involves considering such things as:
• Adding or subtracting something
• Changing the colour
• Varying the materials
• Rearranging the parts
• Varying the shapes
• Changing the size; and
• Modifying the design or the style

**Morphological Analysis:** Any systematic attempt to classify a system in terms of its components is essentially a morphological analysis (Zwicky, 1948). This approach is employed in a qualitative manner, in assisting in a systematic search of a complex problem or system. This technique has been used in many contexts, including product design, technological innovation, market research and social problem analysis. The technique is clearly ideal for generating a large number of ideas of an exploratory or opportunity-seeking nature. It is (Majaro, 1991) suggested that this technique is especially useful for generating ideas about:

• New products or services
• Applications for new materials
• New market segments and Applications
• New ways of developing a competitive advantage
• Novel promotional techniques for products or services; and
• Identification of new location opportunities

**Component detailing:** This technique combines features of attribute listing and morphological analysis (Wakin,1985). The steps are as follows:

1. Working as a team the group members list the major components of the problem.
2. The attributes of each component, are identified and listed by the group.
3. Individual members of the group are given a different problem component.
4. The group member studies the component and its attributes, noting all the details.

5. Each group member draws a picture of his or her assigned component showing as much detail as possible.

6. Drawings are then collected and displayed, so that they are visible to all group members. Attention should be given to displaying the pictures in a logical order.

7. The collage is examined for possible ideas.

This technique is quite useful for looking at product improvement, although many different kinds of problems can be studied.

1.12 Computer Science Education in Tamil Nadu

Computer education in Tamil Nadu has three important streams as listed below:

i. B.E (CSE) & B. Tech., (IT) in Engineering Colleges.

ii. M.C.A., / M.Sc.,(IT) / M.Sc.,(CS) in Engg., / Arts & Science Colleges.

iii. Non-formal computer courses offered in private institutions of both well organized and unorganized.

This research work takes into account of the extent to which creativity is nurtured in all these three streams and attempts to compare them critically. Most of the curriculum components like Text books, Question papers, Teaching Methods adopted, Lab Practice, Student project works etc., have been taken into account.

Engineering Colleges in Tamil Nadu were under the following universities till the year 2001-2002.
1. University of Madras
2. Madurai Kamaraj University
3. Bharathidasan University
4. Bharathiar University
5. Manonmaniam Sundaranar University

In the academic Year 2001-2002, around 220 Engineering Colleges in Tamil Nadu, which were affiliated under these universities, were brought under one Technical University i.e., Anna University. Since all the Engineering Colleges were brought under the same university, the syllabus of B.E., degree programme of all the branches was revised, in order to incorporate the latest technological developments and to keep in pace with the rapid advancement of I.T.industry.

The revised syllabus of B.E. (Computer Science & Engineering) has six theory and two laboratory subjects in each of the first seven semesters and only two theory subjects and a project work in the eighth semester. The following problem-oriented projects have three lecture hours and has totally sixty hours per semester.

1. Analog and Digital Communication
   Lecture –45, Tutorial -15, Total=60
2. Digital Signal Processing
   Lecture-45, Tutorial-15, Total=60
3. Microprocessors
   Lecture-45, Tutorial-15, Total=60

**Elective Subjects with Tutorial hours**

1. Digital Speech and Image processing
   Lecture-45, Tutorial-15, Total = 60
2. Software Testing
   Lecture-45, Tutorial-15, Total = 60
The following subjects do not have tutorial classes and have 45 Lecture Periods per Semester.

1. Operating Systems
2. Theory of computation
3. Computer Architecture
4. Computer Networks
5. Principles of compiler design
6. Software Engineering
7. Object Oriented System Analysis and Design
9. Web Technology
10. Design of Algorithms (Elective)
11. Parallel Computing
12. Neural Computing (Elective)
13. Real Time Systems (Elective)
14. Pattern Recognition (Elective)
15. Parallel Algorithms (Elective)
16. ATM Networks (Elective)
17. Multimedia (Elective)
18. Advanced Databases (Elective)
19. High Performances Microprocessors (Elective)
20. Robotics (Elective)
21. Visual Programming (Elective)
22. Advanced software Engineering (Elective)
23. Graph Theory (Elective)
24. Custom Computing (Elective)
25. UNIX Internals (Elective)
26. Distributed objects (Elective)
27. Advanced Java Programming (Elective)
28. JAVA Virtual Machine (Elective)
29. Component ware Architectures (Elective)
30. Mainframe computing (Elective)
31. C# and .NET Framework (Elective)
In addition to the above theory subjects, the following laboratory courses are also studied to enhance the practicality in professional pursuits.

1. Microprocessor Laboratory
2. Operating Systems Laboratory
3. Compiler Laboratory
4. Network Programming Laboratory
5. Internet Programming Laboratory
6. Software Development Laboratory

For each of the theory subjects, a textbook and a few reference books are mentioned in the syllabus. For very few subjects, two or three textbooks have been given in the prescribed syllabus of B.E (CSE) of Anna University. Each theory subject has five units of subject content. The question papers will have an essay type question from each of the five units. The question paper will have one compulsory big question (16 marks) from any one of the five units and the remaining questions from other units will have 'either or' type of choice.

In addition to theory and practical classes, B.E (CSE) students of Anna University will also have two guest lecturers by experts from industry and one industrial visit for each semester. Students are also encouraged to take seminars on suitable topics in the theory subjects and on emerging technical topics.

It may be noted that there is an Elective Subject entitled CREATIVITY, INNOVATION AND NEW PRODUCT DEVELOPMENT. It has four units as found below:

UNIT 1 Introduction

The Process of Technological Innovation – Factors contributing to successful Technological innovation -The Need for Creativity and Innovation – Creativity and problem solving – brainstorming different techniques.
UNIT 2  Project Selection and Evaluation

Collection of ideas and purpose of project – Selection Criteria-Screening ideas for new Products (Evaluation Techniques)

UNIT 3  New Product Development


UNIT 4  New Products Planning


Even though there is a course exclusively on ‘Creativity, Innovation and New Product Development’, it is noteworthy that this course is offered as an elective subject and so students who are learning this subject will have an opportunity to get enough exposure on the concept of creativity and its importance of new product development. It is also to be remembered that this subject deals with providing the general exposure only on the concept of Creativity. There is no specific mention in the syllabus of this course on the applications or different methods of creative thinking or creativity-oriented, direct or indirect action verbs. Only by incorporating such direct or indirect creativity-oriented action verbs, core capabilities such as programming skills, system simulation, originality in VLSI design, System Design etc., of Engineering students will be honed.

It may also be noted that this subject, since it is offered as an elective, many faculty members are not keen about improving the awareness on the importance of this subject; accordingly, they would not be in a position to inculcate the importance of this subject to the students concerned.
In the academic environment, there are three important practical situations, which encourage the application of creativity or lateral thinking. They are
(i) Description
(ii) Problem Solving
(iii) Design.

While students have to pay more attention to logical thinking for most of the subjects, they must also develop their ability to think creatively in order to perform well in the above three areas. It is noteworthy that these skills are predominantly required for executing innovative, industry-sensitive projects.

### 1.13 Hungerford’s Diffusion / Infusion Curriculum Model

Out of various curriculum models, two models of Hungerford (1989) are very much talked about and used in Engineering Curriculum Design. The first one is known as Hungerford’s Diffusion model, otherwise known as ‘Stand-Alone’ Model. The second one is known as Hungeford’s Infusion model, otherwise known as ‘Integrated’ Model. The essential features of these two models may be extracted from the work done by Hungerford (1989).

The Hungerford's Diffusion model, which is being adopted currently and followed by the Anna University, is presented in Fig 1.2.
Fig 1.2 Currently used Hungerford’s Diffusion Model used in the University Curriculum:

From Fig 1.2, it can easily be understood that the various components of creativity are diffused to the students, as a subject viz., ‘Creativity, Innovations and New Product Development’ in various Engineering disciplines such as Computer Science & Engineering etc.; This subject ‘Creativity Innovation and New product Development’ is offered as an Elective subject to various branches of Engineering in Anna University.

The Infusion Model presented in Fig 1.3, refers to the Computer Science & Engineering discipline alone. Through this research study, the researcher suggests this proposed Infusion Model to the University, for the discipline “Computer Science and Engineering”. This entire research is based on this Infusion Model also known as Integrated Model. The Merits and Demerits of both these models are given in Tables 1.1 & 1.2 as found in the following pages.
Fig 1.3 Proposed Hungerford’s Infusion Model for CSE course of the University:

- Data Structures
- Algorithm Analysis & Design
- Creativity Components: Direct Action verbs & Indirect Action verbs in Description of subjects, Design of Syllabus, Question papers, Students’ Project Work Class room teaching etc.,
- Mini Projects
- Student Project Works
- etc.,

Table 1.2 Merits and Demerits of Diffusion Model

<table>
<thead>
<tr>
<th>S.No</th>
<th>MERITS</th>
<th>DEMERITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Relatively easy to design a new subject or full course rather than infusing various components into the existing subjects</td>
<td>Additional time is to be allocated in the time schedule to accommodate this new subject. The time allocated for other subjects is to be reduced in the schedule, as the total teaching time remains constant</td>
</tr>
<tr>
<td>2</td>
<td>Teachers of the already existing subjects need not be trained in these new areas, as specialist teachers would be appointed for teaching this subject</td>
<td>New teachers specialized in this area are to be appointed separately. This would increase the total budget of the Institution</td>
</tr>
<tr>
<td>3</td>
<td>The Curriculum of the existing subjects need not be disturbed at all</td>
<td>As most of the Computer subjects do not fall under creativity, students may not be able to link these concepts with subject contents. This may not give the idea of ‘Creativity in Computer Science’ to the student, as there is no integral approach in the study. There is only compartmentalized approach</td>
</tr>
</tbody>
</table>
### Table 1.3 Merits and Demerits of Infusion Model

<table>
<thead>
<tr>
<th>S.No</th>
<th>MERITS</th>
<th>DEMERITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Additional time need not be set apart in the schedule, as the 'Creative abilities' are infused into the existing subjects in the respective places. No additional subject or course need to be designed. Total burden on Curriculum design is reduced</td>
<td>Relatively difficult to design the 'Computer Science Curriculum' as per this model, as the creativity aspects are to be infused into the existing subjects at the respective places. Curriculum Design is quite 'time consuming'</td>
</tr>
<tr>
<td>2</td>
<td>No additional or specialist teachers need to be appointed separately. Existing teachers will do these areas also very well. Total budget of the Institution will not rise.</td>
<td>The teachers, who are already teaching the existing subjects, have to be trained completely in these new areas, as they may be unaware of such new areas</td>
</tr>
<tr>
<td>3</td>
<td>As the creative aspects are studied by the students in an integrated manner at the same time, the students get naturally trained with 'Creative abilities'</td>
<td>The Curriculum of the existing subjects need to be totally disturbed. As these new areas are to be infused into the existing subjects, some content areas of them, have to be removed to cope up with the overall course time available. This has to be done with utmost care.</td>
</tr>
<tr>
<td>4</td>
<td>Computer Programmer or Engineer would be more creative or productive and be a natural leader. No need to appoint separate managerial leader, who would be creative to supervise a programmer. This would bring down the establishment cost of the industry</td>
<td>This model is not in vogue in Anna University. Hence, if introduced, lack of familiarity or unfamiliarity would hinder. It takes time for the system to get familiar with this new approach</td>
</tr>
</tbody>
</table>
1.14 The need for the study

It is widely felt that Computer Engineering is a very important profession for sustaining the present day’s knowledge society. Accordingly, the Computer Engineering curriculum which consisting of current syllabus, class room teaching methods, examination question papers etc., play a key role in fostering the inherent ‘Creativity’ possessed by Computer Engineering students. But unfortunately it is reported that a number of Computer Engineering students who graduate from technical institutions, are unable to achieve this professional goal. It is also found that ‘Creativity’ as a competency has not been incorporated in any Computer Engineering curriculum especially in South India. It is also found that the ‘Creativity’ competency has not been scientifically incorporated in both Formal and Non-formal Computer education in the State of Tamil Nadu.

This research work aims at the following studies:

1. To find out to what extent ‘Creativity’ as a competency component, exists in the curriculum and how it is nurtured or suppressed in imparting with Computer education, in particular, in the Engineering institutes. The study would however be limited to Anna University of Tamil Nadu.

2. To attempt in comparing the above findings with that of another institutionalized formal Computer related discipline, viz. M.Sc., (IT). This study would be limited to the University of Madras of Tamil Nadu.

3. To attempt in comparing the above study with that of selective Non-formal Computer Education in Tamil Nadu.

4. To arrive at a benchmark for the quantum of ‘Creativity’ competency in various streams of Computer Technology students of Tamil Nadu and also to compare the above results.
5. To select various components of Computer Technology curriculum for the
detailed study and to suggest means of improving the ‘Creativity’ competency
in them.

This research study would also focus on the development of different
instruments for the proposed study and to execute ‘Survey methods’ in addition to
‘Content analysis’ and ‘Interventions’.

1.15 The Problem and Scope of Study

In accordance with Bloom’s pedagogical taxonomy of human mental skills,
the order of importance of mental skills, is as provided in the list given below:

1. MEMORIZING
2. KNOWLEDGE
3. UNDERSTANDING (COMPREHENSION)
4. ABILITY TO APPLY KNOWLEDGE
5. ANALYSIS
6. SYNTHESIS
7. EVALUATION
8. PROBLEM SOLVING ABILITY
9. EFFECTIVE COMMUNICATION or ELABORATION
10. CREATIVITY or CREATIVE THINKING

The presently existing curricula of B.E. Computer Science and Engineering,
M.Sc (IT) and non-formal courses in Computer education do not pay enough
attention in fostering the ‘Creativity’ competency to the students of these courses.
Hence these students, who are fit enough for choosing high profile careers in
Computer Engineering like professional researcher, systems analyst, enterprising
entrepreneur etc., tend to choose professions, which may not utilize their ‘Creativity’
competency. This is primarily due to the fact that the ‘Creativity’ competency is not
scientifically infused into the academic environment through various components of the curricula (such as Syllabus, Question papers, teaching methods adopted in classrooms, laboratory experiments, project works etc.,)

The scope of the present research work includes the following:

1. To what extent the ‘Creativity’ competency is required for Formal and Non-formal courses of Computer Technology?

2. To what extent, the ‘Creativity’ competency is infused in the textbooks, question papers and Teaching methods adopted in the university curriculum of B.E (CSE), M.Sc., (I.T) and other Non-formal courses?

3. How is the presence of ‘Creativity’ competency compared in various Formal and Non-formal courses of Computer Technology?

4. How to improve the presence of ‘Creativity’ competency in the curriculum of B.E (CSE)?

The results of the current research work that is proposed to be carried out, might create an awareness among the educationists, who are responsible for setting criteria for developing the curriculum of formal streams of Computer and IT related courses viz., B.E (CSE), M.Sc (I.T), MCA and Non-formal computer courses offered by public and private sector organizations.
1.16 Objectives:

The following are the main objectives of this research study:

1.16.1 To qualitatively arrive at a percentage of ‘Creativity’ required for different streams of Computer Science and Engineering education in Tamilnadu such as B.E, M.Sc, M.C.A etc.

1.16.2 To study the existing status of ‘Creativity’ presence in the existing curriculum of formal Computer Education systems like B.E, M.Sc and Non-formal Computer courses in Tamilnadu.

1.16.3 To perform a content analysis on the Anna University question papers of B.E (CSE) so as to find out the percentage of ‘Creativity’ in various subjects pertaining to B.E (CSE).

1.16.4 To perform a content analysis on the prescribed Textbooks of the University of Madras M.Sc (IT) so as to find out the percentage of ‘Creativity’ in various subjects.

1.16.5 To study the provision for creativity in various components of Non-formal Computer Education in Tamilnadu.

1.16.6 To compare the ‘Creativity’ competency in various components of formal and non-formal Computer Education.

1.16.7 To suggest methods in improving the presence of ‘Creativity’ competency in various components in the curriculum of B.E.(CSE).
1.17 Research Questions

1.17.1 Whether ‘Creativity’ competency has been implemented significantly in the curriculum of B.E (CSE) of Anna University through infusion into every subject?

1.17.2 Whether the presence of ‘Creativity’ competency is uniform in all the components of B.E (CSE) curriculum?

1.17.3 Whether the presence of ‘Creativity’ competency is uniform in all the University question papers of B.E (CSE)?

1.17.4 Whether the presence of ‘Creativity’ competency is uniform in all the subjects (unit content) and prescribed textbooks of B.E (CSE) syllabus?

1.17.5 Is there any significant difference in ‘Creativity’ competency between the examination question papers and other components of the curriculum?

1.17.6 Whether ‘Creativity’ competency has been uniformly implemented in the curricula of other Formal { M. Sc., (I.T) } and Non-formal computer education in the state of Tamil Nadu?