CHAPTER II
REVIEW OF LITERATURE

2.1 Introduction

Many sources of reference on ‘Creativity’ as a general psychological term have, widely been, seen in project reports, research works and conference proceedings. However, literature in the areas of ‘Creative ability’ with particular reference to Computer Engineering Education is found to be relatively few. Chronological study (survey) explored in the areas of ‘Creativity’ and its impact on Computer Engineering Education, is discussed in this chapter. Only important and relevant literature concerned with this thesis work, is briefly presented here.

2.2 On Concepts of Creativity & Creativity as a Process

2.2.1 Kelly (1945) and Rogers (1954) maintain that creativity can be maintained by gaining insight into our own understanding of a subject.

2.2.2 Wertheimer (1945) suggests that creative thinking involved breaking down and restructuring our knowledge about a phenomenon in order to gain new insights into its nature. Understanding how see things, may therefore have, considerable influence on our ability to think creatively.

2.2.3 Carl H. Grabo (1948) has stated that ‘considering man’s hostility to change and innovation, it is astonishing that so much of creative and imaginative genius has contrived to leave its impress on the human race. Yet who can doubt that more, inhabited in weak bodies, blasted early by ignorance and cruelty and superstition, has perished with no record? In our comparatively low civilization, a little is done under favourable circumstances to salvage great talent, to give it opportunity to grow and express itself. Yet, how pitifully meager is our salvage and how great the waste! We know that this is so. A more civilized time than ours, will strive to develop this, the greatest of all natural resources’
2.2.4 Guilford J.P. (1950) while delivering the presidential address of the American Psychological Association, emphasized the ‘appalling neglect’ of the study of creativity, indicating that of some 121,000 titles indexed in Psychological Abstracts from its beginning until 1950, only 186 were definitely related to the subject of creativity.

2.2.5 From the early literature on ‘Creative’ ability, it is observed that, Guilford, J.P. (1952), one of the earliest researchers on ‘Creativity’ has found about the implications of creative thinking abilities of human beings.

2.2.6 Guilford (1952) states that, ‘like most behaviour, creative activity probably represents to some extent many learned skills. There may be limitations set on these skills by heredity; but I am convinced that through learning one can extend the skills within those limitations’. This shows that Creativity may be assumed as a competency component along with other Bloom’s cognitive taxonomy.

2.2.7 Vinacke, W.E, (1952) opines that there are two similarities between the creative processes in art and science. In both there is some preparation, although the nature of preparation may differ considerably. In science, the preparation part consists of a trained mind becoming aware of a problem and the attempts at solving it by recourse to scientific procedures, logic or evidence. In art, the preparation part usually consists of being moved or stimulated by some experience.

2.2.8 Alex F. Osborn’s (1953) textbook, ‘Applied Imagination’ emphasizes the importance of imagination in all walks of life, the universality of imaginative talent and the use of creativeness in all stages of problem solving from orientation to evaluation. This book also quotes Albert Einstein’s saying ‘Imagination is more important than knowledge’.
2.2.9 Alex F. Osborn (1953) also suggests that we generate creative ideas by visualizing the subject in new or unique ways. His verbs suggest manipulating the subject in some way, such as changing its size, function or position. Osborn's list of verbs is magnify, minify, rearrange, alter, adapt, modify, substitute, reverse and combine.

For example, consider a group in a food processing company looking for innovative ways to increase sales of packaged food. Creative ideas stimulated by the manipulative verbs might include the following:

Magnify Convert more products to giant-sized packages. Create a store display that is a giant replica of the food product (which might attract children). Make the printed directions on the package large and market this feature to senior citizens.

Minify Convert more products to single-serving packages and market the feature to people, who cook only for themselves. Reduce the portions in packages of snack foods and market this feature to weak-willed dieters, who just can't stop eating until the package is empty. Market a line of food products that is solid only through mom-and-pop grocery stores and generate interest through a nostalgic advertising campaign.

And so on with other verbs also.

Osborn's technique stimulates the imagination by using the mind's ability to visualize things that do not yet exist. It also relies on the fact that our memory patterns for words, can have a large number of associative links to other concepts.
2.2.10 Alex F. Osborn (1953) also proposed that creative thinking involved three stages: They are 1. Fact Finding 2. Idea Finding and 3. Solution Finding.

He further suggests that in 'Idea Finding', judgment should be deferred during idea generating. He feels that if judgment is not made immediately after its proposal, one can focus too much on maximum number of ideas generated and accordingly it may lead to a situation in which high quality solution could be obtained.

2.2.11 Getzels and Jackson (1958) and Torrance (1960) state that the creative thinking abilities contribute importantly to the acquisition of information and various educational skills.

2.2.12 Sigmund Freud, (1959) is of the opinion that a person creates to release or act out his or her inner tensions. Thus, creation is a relief from tension, a sort of indirect catharsis, culminating in the fulfillment of unconscious wishes.

2.2.13 Taylor, C.W. (ed.) (1959) explains about the University of Utah Research Conference held in 1959, on the identification of Creative Scientific Talent. To achieve this purpose, a Committee was appointed to report on ‘the role of educational experience in the development of creative scientific talent’. The Committee reported that at least six research projects had indicated that creative productivity can be developed by deliberate procedures.

2.2.14 Elnora Schamel (1960) of the University of Southern California has established the importance of ‘Creativity’ as a tool for measurement of achievement. The researcher’s work expresses that “the findings of this study indicate that creative thinking abilities do contribute to currently measured achievement and to measures of desirable achievement”. This indicates that the term ‘Creative Ability’, which is the central theme of this research work, may be used as a measure of achievements required in Computer Engineering Education. The term ‘Creativity’ is synonymously used with the term ‘Creative Ability’.
2.2.15 Torrance E.P. (1961) argues that 'perhaps the most promising area, if we are interested in what can be done to encourage creative talent to unfold, is that of experimentation with teaching procedures which will stimulate students to think independently to test their ideas and to communicate them to others'. This shows that curriculum which includes teaching methodology, syllabus content, student evaluation, etc., are expected to play a major role in understanding and developing Creative Ability among the students.

2.2.16 A study of Sommers (1961) reported that mastery of subject matter increased, along with creative ability scores, as a result of weaving creative problem solving into existing courses, in educational institutions.

2.2.17 Psychologist Abraham Maslow (1962) and Stein (1974) have observed that, it is reasonable to expect that each one possesses some measure of 'Creative' ability characteristics. Nevertheless, highly creative people tend to exhibit more of these traits to a greater degree of intensity.

2.2.18 Abraham Maslow (1962) has also distinguished between primary creativity and secondary creativity. Spontaneous creation as that happens in child art, belongs to primary creativity. Secondary creativity is more deliberate and skilled, as in applications of ideas and insights to inventions.

2.2.19 Mary Henle (1962) states that 'Perhaps the most astonishing thing about creative thinking is that creative thinkers can tell us so little about it'.

2.2.20 Paul H. Davis (1962), while predicting forthcoming changes in colleges, states; 'In the last one hundred years, the medical profession has changed from folklore to science, from opinions based on hunches to judgments based on controlled experiments. Now the teaching profession is starting a similar transition'. One of his predictions was that there would be less emphasis on memory and more on creative thinking.
2.2.21 Torrance E.P. (1966) defines that 'Creativity is a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies and so on; identifying the difficult; searching for solutions, making guesses or formulating hypotheses about the deficiencies, testing and re-testing these hypotheses and possibly modifying and re-testing them and finally communicating the results'. Torrance's definition resembles what others have referred as problem solving.

2.2.22 Koestler (1967) expresses the notion that applying procedures from one area of knowledge to another, can give rise to novel associations and that such associations can form the basis of creative ideas.

2.2.23 Guilford J.P. (1968), has noted that 'The unique feature of divergent production is that a variety of responses is produced. The product is not completely determined by the given information. Divergent thinking comes into play whenever there is trial-and-error thinking. Further, in divergent thinking operations, we think in different directions, sometimes searching variety. In convergent thinking, the information leads to one right answer or to recognized best or conventional answer'.

2.2.24 Hinton (1968) combined the creative process and problem solving process into what is now known as creative problem solving. He believed that creativity would be better understood, if placed within a problem solving structure. Creative problem solving is a subset of problem solving based on the assumption that not all problems require a creative solution. He surmised that when a problem is solved with a learned response, then no creativity has been expressed. However, when a simple problem is solved with an insightful response, then a small measure of creativity has been expressed; when a complex problem is solved with a novel solution, then genuine creativity has occurred. Genuine creativity is the result of the creative process that manifests itself into a creative product. Understanding the creative process
plays an important role in enhancing the production of creative products produced within the purview of technology.

2.2.25 Raymond B. Cattell and H.J. Butcher (1968) have stated that 'The person who invents a window fastener, composes a college fraternity song, arranges items in a store in a new way, or makes a pleasant design of the flowerbeds in garden, is performing the kind of creative act that, repeated a million times, benefits society perhaps as much as do the greater inventions.

2.2.26 Guilford J.P. (1968) has stated that 'creative acts can be expected, no matter how feeble or how infrequent, of almost all individuals'.

2.2.27 Edward De Bono (1970) envisages lateral thinking as a description of mental process leading to new insights. For him, the twin aspects of lateral thinking are first the provocative use of information and second the challenge of accepted concepts.

2.2.28 Anthony Storr, (1972), suggests that 'Even though some form of mental sickness seems to be the driving force for creativity, there is evidence that creative persons are in most of the cases, mentally healthy'.

2.2.29 Paul Torrance E. (1979) has stated that 'while divergent thinking is undoubtedly the distinguishing characteristic of creative thinking, there is a place for convergent thinking, too. In grasping what an unclear problem is, a good deal of logical, convergent thinking is needed. Also, once the divergent thinker makes some critical choices, once an original line of thinking or line of enquiry is established, a good deal of convergent thinking ability must come into play. Categorization, logical thinking, analysis, comparing, evaluation and so forth, the stock-in-trade of convergent thinking, becomes critical in this phase of problem solving. Indeed, quite often creative thinking consists of alternative phases of imaginative (divergent) and rational (convergent) thinking.'
In accordance with Hayes (1990); Stein (1974), Taylor (1959) and Torrance (1963) ‘Creativity is a process that has been represented using various models. Graham Wallas (1962) offered one of the earliest explanations of the creative process. His model consisted of four stages as mentioned below:

1. **Preparation:** This is the first stage in which the individual identifies, investigates a problem from many different angles.

2. **Incubation:** At this stage the individual stops all conscious work related to the problem.

3. **Illumination:** This stage is characterized by a sudden or immediate solution to the problem.

4. **Verification:** This is the last stage at which time the solution is tested.

Wallas’ model has served as a foundation upon which other models have been built. However researchers Stein (1974), Taylor (1959), Torrance (1966) have added the communication stage to the creative process and it is the final stage of the entire creative process.

Perkins, D. (1981) and Weisberg (1986) argue that there is nothing peculiarly special about creativity and that it draws upon perfectly normal cognitive processes such as recognition, reasoning and understanding. The essence of this argument is the notion that ‘Chance favours a prepared mind’. Perkins (1981) also quotes Sternberg as arguing that insight depends on three processes; selective encoding of information, selective combination – that is synthesizing appropriate information and selective comparison – relating new information to old.

Ainsworth-Land (1982) has proposed four levels of creativity; Elaborative, Improvement-oriented, Combinations or synthesis of superior quality and transformation (such as the emergence of a new approach or paradigm shift through the destruction of the old).
2.2.33 A frequently asked question among educators is, ‘What is the relationship between creativity and intelligence?’ Researchers have always been curious in finding out the relationship between creativity and intelligence and have shown that there is no direct correlation between creativity and intelligence quotient (I.Q.). { Edmunds (1990), Moss (1966), Torrance (1963) }. Edmunds (1990,) conducted a study determining whether there was a relationship between creativity and I.Q. Two hundred and eighty-one randomly selected students, from grades eight to eleven, from three different schools in New Brunswick, Canada participated in the study. The instruments used to collect data were the Torrance Test of Creative Thinking and the Otis-Lennon School Ability Test, which was used to test intellectual ability. Based on a Pearson product moment analysis, results showed that I.Q. scores did not significantly correlate with creativity scores. The findings were consistent with the literature dealing with creativity and intelligence. Hayes (1990) asserts that on a practical level, findings similar to the one above may explain why I.Q. measures have proven to be unsuccessful in predicting creative performance.

2.2.34 In the event of comparing Torrance’s (1966) definition of creativity with that of Savage and Sterry’s (1990) problem solving process, one can easily see similarities between the descriptions. Guilford (1976), a leading expert in the study of creativity, made a similar comparison between steps of the creative process offered by Graham Wallas, with those of the problem solving process proposed by the educational philosopher John Dewey. In doing so, Guilford simply concluded that, ‘Problem Solving is creative; there is no other kind’. Nevertheless, Stein (1973) would argue that creativity is more than problem solving and points out that creativity is different from problem solving in that, creativity involves a mystical phenomenon. This phenomenon is characterized by inspiration, intuition, and aesthetic feeling that are evoked by the ‘Eureka’ or ‘Aha’ experiences. He maintains that creativity is dependent more on the emotional and irrational aspects, whereas problem solving is best seen as depending more on intellectual processes.
2.2.35 Roger Von Oech (1983) suggests that we can generate useful ideas by starting from an outrageous, impractical idea. Accepting the outrageous idea causes us to temporarily suspend our judgment sub-processes, while the idea itself sends us exploring potentially useful valleys in our memory.

2.2.36 Laura Hall Rose and Hsiu-Tai Lin (1984) have found that ‘Experience with creative training also shows significant increases in the creativity of the participants through training’.

2.2.37 It has been suggested that possessing creative ability is an essential asset for any leader (Bennis and Nanus, 1985).

2.2.38 Rausdeep (1987), postulates that there is evidence to support a direct link between organizational efficiency and effectiveness.

2.2.39 Rickards (1988), describes creativity as an escape from ‘mental stuckness’, an operational definition, very much keeping with its role in decision making and problem solving.

2.2.40 It is found that the creative performance may be better predicted by isolating it from investigating personality traits (Hayes, 1990).

2.2.41 Le Bouef, M, (1990), explains the experience of Roger Sperry and his associates at the California Institute of Technology, in their historic split-brain experiments; they were able to separate surgically and test the thinking abilities of each of the human brain. In doing so, they found that each of the brain has its own way of thinking and its own memories. The left brain tends to think in terms of symbols and words, while the right brain thinks in terms of sensory images. The left brain is used for logical thinking, judgment, speaking and mathematical reasoning, while the right brain is the source of dreaming, feeling, visualization and intuition.
Creative thinking requires coordinating and using both sides of the brain. Flashes of insight and intuition are the result of the right brain thinking; but analyzing these insights is the function of the left brain. Research into the thought processes of highly creative people, shows that they rely heavily on the intuitive side of their brain.

2.2.42 According to Aziz M. Abu-Khalaf (2001) of King Saud University-Riyadh, creativity is a learnable and teachable skill. The main problem with it is the lack of clear understanding of it, and in particular, the actual creative part of it. Being creative is not magic; your mind has to develop new ideas; elaborate upon others’ ideas; bring about unusual response, breaking the assumptions.

2.2.43 Brian Cregger (2003) of University of Central Florida conveys that teaching creative thinking should be an important topic that seems to be overlooked by too many institutions at various levels of education.

2.2.44 Alistair Fee (2003) of Queens University of Belfast expresses that Creativity can be logically taught. He also states that Creativity helps in mixing ideas across engineering disciplines to explore many viable options exhaustively.

2.2.45 Ahmed Ibrahim (2003) of Devry Institute of Technology feels that if the level of Creativity already possessed by students is reduced inadvertently, will reduce the natural powers of thinking and imagination in them.

2.2.46 Erol Inelmen (2003) of Bogazici University, Turkey expresses that originality is the most important ingredient of creativity and exercises have to be given to develop the originality of the students at any level.

2.2.47 Runco (2004) states that ‘Creativity is a highly diverse concept that has been studied in disciplines like Economics, Cognitive Science, Developmental Research, Pedagogy and History. While precise operations differ between disciplines, creativity is usually defined as a novelty and appropriateness and has been associated with problem solving and novelty generating ideation, as
well as with reactive and adaptive behaviour, which allows people to cope up
with turbulent environments. Even if psychological perspectives are most
common research on creativity is highly dispersed and multidisciplinary.

2.3 On the Importance of Creativity in Engineering

2.3.1 Torrance (1960) states that ‘by checking information from many sources, it is
alarmingly to note that much creative talent goes unrecognized’. In his studies
at all educational levels, he recalls that over 70 % of those in upper 20 % on
tests of creative thinking, would be eliminated, if only an intelligence or
scholastic aptitude test had been used.

2.3.2 Establishing criteria for evaluating the creative products of industrial arts
(currently referred to as technology education), this has been addressed by
only a few researchers { e.g., Moss (1966), Duenk (1966) } within the
discipline. Moss (1966), in examining the criterion problem, concluded that
unusualness and usualness were the defining characteristics of the creative
product, produced by industrial arts students.

2.3.3 Olson (1973), in recognizing the importance of allowing students to create
new products, has observed that ‘technology was born out of creativity and
the creative imagination is the highest level of the intellect. Emphasis on
intellectual development, to think creatively, is the great imperative industrial
arts (technology education). It draws out the individuality, discovers
idiosyncrasy, establishes identity and demonstrates potential, all essential to
realization of self. Designing with materials, tools, machines, energies, ideas
is the way of technology and the way for industrial arts (technology
education)’.

2.3.4 Olson (1973), in describing the important role that is played by projects in the
technology classroom, has remarked ‘The project represents human creative
achievement with materials, ideas and results in an experience of self-
fulfillment. The continuing student input causes immediate, real and
meaningful feedback enabling the student to assess the achievement at any one time or point in the project.

2.3.5 The Creative Product Analysis Matrix (Besemer & Treffinger (1981)), a theoretical model by which the creative product could be identified and measured, is one of the most comprehensive works addressing the creative product. However, another less noted work on ‘the creative problem solving’ can be found within the discipline of industrial arts.

2.3.6 Besemer and O’ Quin (1993), believe that the creative product is unique in that it combines both the creative person and process in to a tangible object representing the ‘true’ measure of a person’s creative ability. For example, Leonardo da Vinci is deemed creative because of his products, and not due to the results of clinical observation or a battery of physiological tests. Yet, researchers still cannot agree on what creativity truly is, nor what attributes make up the creative product (Besemer & Treffinger (1981); Joram, Woodruff, Bryson & Lindsay (1992); Stein (1974)).

2.3.7 Larry G. Richards (1997), has Stimulated Creativity for teaching engineers to become innovators.

2.3.8 Larry G. Richards (1997) of the University of Virginia expresses that Engineering is a Creative profession; yet few Courses in the standard engineering curriculum require or even encourage Creativity. Engineering Students often feel that creative behaviour is actively discouraged in their classes.

2.3.9 Stamatelos A.M (2000) of University of Thessaly, Greece opines that ‘Implementation of Creativity’ in Engineering Education is one of our most important purposes for restructuring our curriculum.

2.3.10 Costas Neocleous (2000) of the University of Cypress expresses that hard core engineering disciplines certainly need teaching techniques, which would
improve creativity among the engineering students. This would aim at making the engineers more open-minded with a wider view when searching for alternative engineering solutions

2.3.11 Khandwalla P (2000) has emphasized the nature of both convergent and divergent thinking needed in Engineering Designs. He has stated that Creative intelligence consists of alternative phases of convergent and divergent thinking ability. It is axiomatic that the order would vary both by the nature of the problem and the skills and habits of the problem solver.

2.3.12 It is reported by Efraim Turban and Aronson E. Jay (2001) that ‘Associations trigger memories that can activate creativity. Exchanging ideas would increase output and creativity’. Hence group discussions may be emphasized in engineering curricula.

2.3.13 Lawrence Coates (2001) of the School of Engineering, the University of Birmingham, UK feels that a solution for an open-ended engineering design problem may be created in the classroom environment itself, through creative thinking.

2.3.14 Bahrom Akramov (2002) of Tajik Technical University, Tajikistan expresses that developing creativity should be one of the main objectives in teaching the fundamentals of Engineering Courses.

2.3.15 Marion Hayes (2002) of Queensland Institute of Technology expresses that Design is an intrinsically creative practice, which evolves from considerable years of investment in learning, sharing and practising with various levels of Research and Development within the industry and the Organization.

2.3.16 Daniel J. Moore (2003), a Senior Member of IEEE expresses that Current Engineering Education focuses on the rigour and discipline of problem solving using systematic processes, techniques and advanced tools. Increase in the
required technical material has resulted in the neglect of Creativity and imagination in many programs.

2.3.17 William A. Wulf (2003) of the National Academy of Engineering, USA, in his research paper, ‘Diversity in Engineering’ asserts that engineering is a creative profession. Engineers design to solve problems, but an elegant design, which not only solves the problem but also satisfies the constraints, which is one of the most Creative activities, has to be accomplished.

2.3.18 W.B. Stouffer, et al (2004), have analysed on the Creativity and the future of Engineering education, in particular with civil and environmental engineering.

2.3.19 Richard M. Felder et al (2004), have studied on the ABCs of Engineering Education with the Bloom's taxonomy along with cooperative learning.

2.3.20 Henrik Berglund et al (2004), have compared ‘Creativity’ among various entrepreneurship students especially by comparing students of engineering and business education.

2.3.21 Richard M. Felder (2004) in his research paper, on creating Creative Engineers expresses that Engineering requires innovation and Creativity focused in a design process. Design is at the heart of engineering and at where professional engineers demonstrate their creativity and exemplify innovation.

2.3.22 Caroline Baillie et al (2005), has reported their findings in Forum on Creativity in Engineering Education.

2.4 On Creativity in Computer Engineering Education

2.4.1 Torrance (1977) recommends several guidelines to promote creativity in the ‘classroom teaching’ as found in the following steps:
Before a lesson

- Confrontation with ambiguities and uncertainties
- Heightened anticipation and expectation
- Familiar made strange and strange made familiar
- Looking something from several different psychological, sociological, physical or emotional points of view
- Provocative questions to examine information in new ways
- Prediction from limited information required
- Tasks structured only enough to give clues and direction

After a lesson

- Ambiguities and uncertainties played with
- Constructive responses encouraged
- Going beyond the obvious encouraged
- Elaborating some elements through drawings, dramatics, imaginative stories etc.,
- Search for elegant (better) solutions
- Experimentation and testing of ideas encouraged
- Future projection encouraged
- Improbabilities encouraged
- Multiple hypotheses encouraged
- Reorganization or re-conceptualization of the information that is required

In addition, Torrance encourages instructors to develop constructive – as opposed to critical – attitudes in themselves and in their classrooms.

2.4.2 Gallini (1983) and Hendeson & Minner (1991) have stated that ‘Computer programs have advanced beyond the early days of drill and practice instruction and are currently addressing higher order thinking skills, including creativity. However researchers warn that computers alone do not provide
students with the opportunities to be creative, the classroom teacher is still responsible for choosing appropriate software and effectively implementing in the classroom.

2.4.3 Hayes, J.R. (1990) has studied the cognitive processes in creativity, required for research in 'Creative' ability. On a practical level, his findings are similar to the one above and may explain why I.Q (Intelligent Quotient) measures have proven to be unsuccessful in predicting creative performance.

2.4.4 Most educators do not expect students to produce new products, which would characterize creative genius. It is sufficient if the work is appropriate to the task at hand and original within the student's ability according to Dodge, (1991). In trying to understand and predict a person's creative ability, two factors have often been considered: intelligence and personality, according to this researcher. Dodge (1991) has also suggested that creative computing can offer the following advantages to students:

1. **Flexibility, mobility**: the ability to shift perspectives, to redefine a problem in the direction of greater or lesser abstractness.

2. **Fluency**: the ability to generate many ideas, knowing that only a few will be valuable.

3. **Association**: the ability to keep disparate elements together to make new combinations

4. **Testing**: the ability to quickly try out ideas, discarding those that do not work.

Because of its educational potential, computers are getting more abundant in the classroom. If implemented properly, the use of computer may be an effective method in developing the creativity of students.
2.4.5 A study conducted by Joram, Woodruff, Bryson & Lindsay (1992) found that average students produced their most creative work using word processors as compared to using pencil and paper. The researchers hypothesized that word-processing would hinder creativity due to constant evaluation and editing of their work. To test the hypotheses, 31 average and above eighth grade writers, were randomly assigned to two groups. The first group was asked to compose using word-processors while the second group was asked to compose using pencil and paper. After collecting the compositions, both the word-processed and hand-written texts were typed so that they would be in the same format, when presented to a panel of raters. Using a five-point grading scale, the raters evaluated the products for creativity. In order to assess the effects of the experimental factors, a uni-variate analysis of variance was carried out. Results showed that there was a significant three-way interaction skill, medium of production and composing instructions on creativity. Based on the results obtained, the researchers concluded that word-processing enhances the creative abilities of average writers. A reason for this result may be that word-processing helps average writers generate a number of ideas knowing that only a few of them will be usable and the rest can easily be erased. However, the researchers also found that word-processing had a negative effect on the creativity of above average writers. These mixed results suggest that the use of word-processing may not be appropriate for all students.

2.4.6 In a study conducted by Howe (1992), two advanced classes in graphic Design, consisting of 28 undergraduate students were randomly assigned to one of two treatments. The first treatment group was instructed to use a computer graphic program to complete a design project, whereas the other group was asked to use conventional graphic design methods to design their product. Upon completion of the assignment, both groups' projects were collected and photocopied, so that they would be in the same format, when presented to a panel of raters. Using the 'Creative Product Semantic Scale
Besemer & O’Quin (1989), the raters evaluated the products for creativity. Results showed that students using computer graphics technology surpassed the conventional method in all sub-scales of creativity. Howe concluded that computer graphics technology may enable graphic designers to generate abundant ideas; then capture the most creative ones and incorporate them in their designs.

2.4.7 Bilan (1992) has stated that ‘Software designers, today, are able to design multidimensional educational programs that include high quality graphics, stereo sound and real-time interaction’.

2.4.8 Dale Spender (1996), has found some relations between ‘Creativity’ and the computer education Industry.

2.4.9 Knoll (1997) has mentioned that ‘Technology educators have chosen the creation of products or projects as a means to reach technological concepts’.

2.4.10 In his article, ‘How Creative Engineers think’, Tom Peters (1998), explores the creative problem solving of leading engineers such as Gustave Eiffel. Based on archival data, Peters determined that many groundbreaking design concepts stem from simple, often sublime reformulations of current thinking and practice and that these creative breakthroughs are often fed by study and observation outside of engineering paradigms.

2.4.11 Richards (1998), has stated that ‘Creativity is an essential component in Engineering design; but most of the Engineering schools do not adequately prepare students for creative endeavors or for the realities of modern industry’.

2.4.12 Richards (1998) additionally recommends a series of activities to incite creativity, when faced with an Engineering problem

- Immerse yourself in a domain or problem;
- Be prolific – generate lots of ideas;
• Use tools for representations and thoughts;
• Play with ideas;
• Avoid premature closure;
• Don’t be afraid to be different;
• Be open and receptive to new ideas;
• Do it – practice your craft;
• Maintain a product orientation
• Relax – indulge your diversions;
• Reflect – review what you have done;
• Have fun!

2.4.13 Richards (1998) also states that ‘As educators we are responsible for stimulating creative thinking among our students. Our ultimate goal is to require original creative work as part of every engineering course’.

2.4.14 Cropley, A.J. (2000) found that ‘Creativity is the most important requirement for those who aspire to become entrepreneurs especially in the field of Information Technology’. Hence the importance of ‘Creativity’ is again felt in the area of Computer Science or Information Technology.

2.4.15 Jeh-Lou Meng, (2001), has studied on Creativity in Engineering Curriculum, with a specific case study on the Department of Technology Education in Professional Colleges.

2.4.16 According to Richards (2002), the desirable development of skills of creativity and innovation in Engineering undergraduates is a forgotten practice. Thus time has come to incorporate creative competency as one of the objectives in the curriculum of Computer Science and Engineering. This has been observed in one of the Hypotheses of this research work.

2.4.17 Richards (2002) has also stated that, although most Engineering students feel that Engineering is a creative profession, the names of engineers are rarely included in their lists of creative people. One problem seems to be that
students don’t know the names of many creative engineers. This may be because of the fact that many of them are part of the results from the efforts of large teams or organizations. Engineering advancements are often incremental improvements on existing products, not due to major breakthroughs, which might bring public recognition. And it is feared that most engineering professors don’t emphasize in their classes, the names of renowned engineering professionals who were responsible for our greatest technological achievements.

2.4.18 Santamarina (2002) warns that ‘Teaching creativity has limited impact if it is not immersed in problem solving exercises’.

2.4.19 Daniel J. Moore et al (2003), has studied on the curriculum of Engineering with ‘Creativity’ ability.

2.4.20 Raskin (2003) states that ‘Taking a creative look at Engineering Education does not mean ignoring or choosing to disregard the normal project parameters or technical constraints that must be imparted to the next generation of professionals. Instead, using creativity can mean generating excitement in students as they approach engineering problems in original ways’.

2.4.21 Gerald Estrain (2005), has elaborated on his reflections on creativity in the history of Computer Science & Engineering / Information Technology.

2.4.22 Bagheri K (2004) of Esfahan University, conveys that education can promote inherent creativity possessed by students by developing the Curriculum properly.

2.4.23 It has been demonstrated by Lumsdaine E et al (1995) that Creative thinking can enhance our use of computers and the way we interact with people. It can improve how we integrate various learning techniques with computers in the service of the students and society, while communication is the
important connecting link. Thus computers play an active role in improving the communication among the end-users and enhance creative thinking, visualizing and creative problem solving.

2.5 On the Analysis of Creativity

2.5.1 Schamel, Elnora (1960) has related with the relationship of creative thinking abilities to school achievement among school students.

2.5.2 Torrance E.P. (1961) has found relationship with the status of concerned knowledge gained from education and the creative scientific talent.

2.5.3 Abraham Maslow (1962), after studying several of his own works, determined that all people are creative, not in the sense of creating great works, but rather, creative in a universal sense that attributes a portion of creative talent to every person.

2.5.4 Olson (1973), in recognizing the importance of allowing students to create new products, stated: technology was born of creativity and the creative imagination is the highest level of the intellect. So enough emphasis has to be laid in the curriculum to nurture it.

2.5.5 Richard M. Felder (1987), expresses the opinion that ‘The toughest problems facing our society – how to provide all our citizens with adequate and affordable food, housing and medical care, efficient and economical public transportation, clean and safe energy – are not likely to be solved by easy or conventional means. If they could be, they would have been solved by now. To the extent that the problems are technological, creative engineers are needed to solve them. We, Engineering Professors, are in the business of producing engineers. It would seem our responsibility and also in our best interest, to produce some creative ones – or at least not to extinguish the sparks of creativity, our students bring with them.'
2.5.6 Besemer, S.P., & O’ Quin, K (1993) have assessed creative products viz., Progress and Potentials.

2.5.7 Decker, D.L, (1995), states that ‘While the main requirement of engineering is not to be creative, but to be disciplined; Engineers must employ both analytical / deductive(convergent) thinking and more inductive and divergent (Imagining lots of possibilities) ways of thinking in their work. The design process requires judgment, creativity and discipline as well as technical skill’.

2.5.8 Sharma (1963) confirms that the use of action verbs of creativity has proved to be effective. These verbs have been collected from several important sources.

2.5.9 Carlos Santamarina, J. (1998), asserts that ‘While the manifestations of ‘Engineering creativity’ are overwhelming in everything that surrounds us, the nature of ingenuity and creativity remains elusive. Furthermore, it can be argued that today’s education system neither promotes ingenuity nor provides all the necessary tools to sustain it’.

2.5.10 Runco, Nemiro, and Walberg (1998), conducted a survey investigating the personality traits associated with creative persons. The survey was mailed to 400 individuals who had submitted papers and/or published articles related to creativity. The researchers asked participants to rate, in order of importance, various traits that they believed affected their creative achievement. The survey contained 16 creative achievement clusters consisting of 141 items. One hundred and forty-three surveys were returned reflecting a 35.8% response rate. Results demonstrated that intrinsic motivation, problem finding and questioning skills were considered the most important traits in predicting and identifying creative achievement. Though personality traits play an important part in understanding creative ability, an equally important area of creativity theory lies in the identification of the creative process.