1.1 SCIENCE

In our contemporary civilization and culture, science has become a part and parcel of our life. In the advanced countries science has entered the every fabric of life. The modern world is a scientific world and today science is everybody's concern.

Science is not just a body of knowledge as it used to be considered in earlier times; it is a static view presenting science as a host of facts, principles, laws and theories along with the vast lot of systematised information used for interpreting the events in our environment and universe at large.

It is true that ever since men tried to understand nature, and to adjust themselves for existence and survival, human knowledge has accumulated. Man then began to study nature's laws and behaviour systematically and classified the gathered knowledge for convenience. But science is more than this. Science is dynamic. It is knowledge as well as the process of its continuous development and refinement. Nehru remarked well that science does not simply sit down and pray for things to happen but seeks to find out why things happen. It is an endless process of observation, exploration and acquisition through empirical and conceptual means. The characteristics of this process is growth through
continuous acquisition, generalization and refinement.
In science, generalizations often have exceptions. Conclusions in science are valid as long as they can explain all the known events and behaviour in nature. In this sense, generalizations are tentative.

In the words of Sood (1987), science is a multi-dimensional activity and it is very difficult to search a universally acceptable definition of science.

Conant (1947) defined science in the following words, "science is an interconnected series of concepts and conceptual schemes that have developed as a result of experimentation and observation".

Einstein (1959) explained science as, "the attempt to make the chaotic diversity of our sense experience corresponding to a logically uniform system of thought."

As given by Fitzpatrick (1960), "science is a cumulative and endless series of empirical observations, which result in the formulation of concepts and theories, with both concepts and theories being subjected to modification in the light of further empirical observations. Science is both a body of knowledge and the process of acquiring and refining knowledge." According to Griggs (1960), "science in fact is more than a subject, it is a method of acquiring knowledge and of necessity the approach must be corrected."
'The Columbia Encyclopaedia' (1963) defined science as an accumulated and systematized learning in general usage restricted to natural phenomena. The progress of science is marked not only by an accumulation of facts, but by the emergence of scientific method and of the scientific attitude" (cited by Sood, 1987). In the words of Woodburn, Ellsworth and Obourn (1965), "science is that human endeavour that seeks to describe with ever increasing accuracy the events and circumstances that occur or exist within our natural environment."

Thus, three basic assumptions of science can be identified by the above given definitions, as:

(i) science is an accumulated and systematized body of knowledge;
(ii) the scientific method of enquiry, and
(iii) the scientific attitudes.

The first point represents the product of science, and the rest two indicate the process of science. Thus, science is both product as well as a process.

A viewpoint, on the nature of science is given both diagramatically as well as in words by Committee on Changes in School Science Teaching (1970).
The documents have mentioned that:

(i) Science is a body of systematized knowledge.

(ii) Science involves methods of inquiry which help in the growth of knowledge.

(iii) This knowledge had direct and indirect relationship with man and his environment which includes social, moral and ethical consequences.

Bullock (1976) deemed science to be "The greatest intellectual and cultural achievement of man". He perceives science to be an open ended process in which imagination, hypothesis, criticism and controversy - not to mention passion and error - play a role..... Bullock has mentioned "Science as a human study, deeply concerned with man and society, providing scope for imagination and compassion as well as for observation and analysis."

According to Vasistha and Gill (1987), the word
'Science' is derived from Latin word 'Scientia', means knowledge. Thus, knowledge is acquired by scientific method or the procedures of science. Science may be defined as knowledge which is generally accepted because it has been proved to be true and which has been classified and arranged so as to demonstrate general truths or the operation of natural laws.

Some common characteristics can be drawn by careful analysis of these definitions which are as follows :-

(a) Science is an interconnected series of concepts and conceptual schemes which reflects some unifying pattern.

(b) These concepts evolve through the process of experimentation, enquiry or the methodologies of science which include factors from simple observation to developing hypothetical models.

(c) The knowledge of science is related to man and environment, the total and ecological factors which influence the essential part of culture.

(d) Science has its own value of rationality, objectivity morality and ethics related to broad human concern.

1.2 DEVELOPMENT OF SCIENCE IN INDIA

The modern system of education in India grew during the British period which ultimately replaced the indigenous system of education that was in practice in India since
ancient times. During this period science was introduced in Indian schools. Wood's Education Despatch (1854) was instrumental in laying the foundation of the modern system of education in India. Among other things it laid emphasis on the study of science, arts, philosophy and European literature. But the effective beginning was made in 1944 when the Sargent Report was published. Sir John Sargent envisaged two types of schools in India: The Academic High Schools which would impart instructions in arts and pure sciences, and the Technical Schools which would provide training in applied sciences and industrial as well as commercial subjects. At this time it was the beginning of science in schools.

After independence, the first commission on education was set up in 1948, which was known as the University Education Commission. The chairman of this commission, Dr. S. Radhakrishnan submitted the report in August, 1949. This commission discussed the matters concerning higher education and also suggested radical reforms in the secondary education. Fortunately, in India, the national leadership and the educationists have recognized that education will prove helpful in improving the quality of the life of the people as it is directly linked with the national development and progress. It has also been realized that science education is essential for the development of agriculture, industry and technology. So, in post-independence India, the Secondary Education Commission (1952-53) suggested
a scheme of multipurpose schools which required diversification of studies at the end of class VIII and the provision of a variety of courses for students in classes IX to XI. In this scheme, science, commerce and technology were some of the important courses.

In 1956, the All-India Council for Secondary Education organized an All-India Seminar on Teaching of Science at Tara Devi, Simla and laid emphasis on the study of science and its relevance in modern Indian Education.

The establishment of the National Council of Education Research and Training (NCERT) in 1961 was the most important landmark in Indian Education. The NCERT established the Department of Education in Science and Mathematics to study and improve school science teaching. It also started the Regional Colleges of Education at Ajmer, Bhopal, Bhubaneshwar and Mysore to provide integrated Teacher education programmes for science teachers, language teachers, commerce teachers and agriculture teachers. The NCERT has also started National Science Talent Search Scheme under which the talented students are identified and nurtured at the national level.

When the First Russian Sputnik was launched on 4th October, 1957, it evolutionized school science in the U.S.A. and other countries. Then the main purpose was to improve science teaching in school, by providing new science textbooks and by laying emphasis on more laboratory work where science
teachers functioned as guides. These American efforts influenced science teaching in the U.K. and India. The first effort in India was the organization of Summer Institute for secondary school teachers. This was a collaborative effort between the University Grant Commission (U.G.C.), the NCERT and the United States Agency for International Development (USAID). Four institutes for science teachers (biology teachers, chemistry teachers, physics teachers, and mathematics teachers) were organized. In this the science teachers were made familiar with new science curricular materials. The NCERT brought the science text books which were developed in USA by The National Curricular Projects. The major emphasis was on the retraining of science teachers so that to enable them to try new experimental approaches and new text materials.

In August, 1961, the Indian Parliamentary and Scientific Committee was constituted. It presented a report which was approved on 17th September, 1963. The report - "Science Education in Schools", discussed the problems of science education in schools with a view to find out the position of science courses and how these were organized in schools at the primary and secondary stages. The main objective was to acquaint the members of Parliament with the problems of science education in schools and how they could help in improving science teaching.

In 1964, Report of UNESCO Planning Mission : "Science and Mathematics Education in Indian Schools" was published.
The report presented observation on the science teacher, laboratory equipment and research in science and mathematics education. The UNESCO Planning Mission felt that the following aims should be encouraged in the schools: (i) to provide the youngsters with fundamentals of science; (ii) to acquaint students with major applications of science; (iii) to teach students the methods of science; (iv) to develop in them observation habits, logical thinking, inquisitiveness, etc., (v) to assist in developing vocational, physical, cultural and aesthetic education of pupils; (vi) to help in shaping modern scientific outlook. This document was hopefully a case for change in science teaching at the school stage.

The Report of Education Commission (1964-65) suggested uniformity in the structure of education. This commission suggested the 10+2 pattern of school education, consisting 10 years of general education and classes XI and XII will provide specialized studies in different subjects. This pattern of 10+2 scheme envisaged study of science right from the lower primary stage in the form of "Study of Environment".

The Document "Mathematics and Science Education in Indian Schools (1965)", which was published by Wanchoo (1965) presented a comprehensive description of science teaching.

The Government of India published National Policy on Education in 1968 which recommended rapid expansion of education and 10+2+3 pattern of education throughout the country.
In 1968, American Peace Corps and the Science Teachers of Andhra Pradesh pooled their experiences in the form of a book which was entitled "Science Teachers Handbook" edited by C.S. Rao. It was a rich resource material for science teachers.

In 1977, Bulletin of UNESCO Regional Office for Education in Asia published its special issue on science education in the Asian Region. This issue described science education in India and presented a comprehensive view.

The curriculum for the Ten-year school: A framework, 1975, envisaged 10+2+3 pattern of education. This document proposed study of science in the form of environmental studies. It supported the view of study of science by all students up to Class X. It was expected that science should help in reducing obscurantism and all sorts of prejudices.

The nation has realized the importance of qualitative growth of teachers. A national body, the National Council of Teacher Education (NCTE) was established in 1976 to advise the Government and other agencies to improve teacher education. The three main areas of teacher education considered in this framework were:

(i) Pedagogical theory.
(ii) Working with the community.
(iii) Practice teaching, related practical work, content-cum-teaching methodologies.
The efforts which were done provided a major trust for indigenous efforts to improve science teaching. Still there was a deepening concern about the quality of education to fulfill the needs and aspirations of the people. The publications: The National Curriculum for Primary and Secondary Education: A Framework, 1985 and the National Policy on Education-1986, were the serious efforts in this direction.

The National Policy on Education-1986 accepted the study of science as an integrated part of 10-year schooling. Thus, study of science would be compulsory in schools right up to Class X.

But, in spite of all these, still India has to develop a lot to keep in pace with the advanced countries. The need of today is not only to develop civic sense, but also a right type of scientific attitude and scientific creativity among the students, because the students of today are the builders of India tomorrow. Without the general understanding of science, scientific material and scientific inventions the civilized life will become impossible in the near future. So, the main responsibility is on our teachers and educational system of developing the heuristic attitude and scientific creativity in scientific areas among the students right from the school stage because creativity constitute an absolutely key element in the building of scientific infrastructure.
1.3 CREATIVITY:

The phenomenon of creativity is too flexible that there is no uniformity in views regarding it. It is in the recent year that systematic and scientific research has been shown in the subject.

In the earlier days, creativity was considered as a divine gift, as an imagination ability, intuition and cosmic fence. Also, the literature is full with terms like originality, insight, adventurous thinking, discovery, problem solving and inventive ability, which has been used synonymously with creativity.

Creativity exists on a continuum. It involves not only one but many abilities; three of these are fluency, flexibility and originality. According to Drevdahl (1956, 1958), "creativity is the capacity of a person to produce compositions, products or ideas of any sort which are essential new or noble, and previously unknown to the producer. It can be imaginative activity or thought synthesis, where the product is not a mere summation. It may involve the forming of new patterns and combinations of informations derived from past experience, and transplanting of old relationships to new situations and may involve the generation of new correlates. It must be purposeful and goal directed not mere idle-fantasy—although, it need not have immediate practical application or be a perfect and complete product. It may take the form of an artistic, literary or scientific production
or may be of procedural and methodological nature."

MacKinnon (1963) defines it, as "a process extended in time and characterized by originality, adaptiveness and realization." The other writers consider it useful to distinguish between the creative and original behaviour. According to them, original behaviour is that which is comparatively less frequent and is uncommon in the given conditions. On the other hand, the creative behaviour is that which is visible in those productions which are considered creative by the associated judges and the products which are having the characteristics of fluency, flexibility, originality and uniqueness. Cattell and Butcher (1968) pointed out that creativity is a vague term, but it describes a quality or a complex of qualities, whose importance can hardly be exaggerated and it appears to be the best term for the wide spectrum of behaviour involved. That spectrum includes scientific discovery, artistic production, musical composition, technological inventions, political and social innovations, literary creation and even religious leadership.

Though so many definitions and explanations have been given to make the concept of 'creativity' clear, yet, there is no complete unanimity among those studying creativity as to what it really means (Barron, 1969; Freeman, Butcher and Christie, 1971). Hallman (1963) gives two reasons for the confusion in conceptual clarity and disagreement among the various researchers, as (i) the tendency to emphasize interests by a wider area of disciplines to investigate the creative
process, and (ii) the complex nature of creative experience. The first view of assigning different meanings to the process of creativity by different investigators has been reported by Vinacke (1952), Ghiselin (1963), Zimmerman (1964), Yamamoto (1964), Romey (1975) and Howley (1979). Whereas, the second view is extensively found in the numerous definitions which Rhodes (1961) attempts to condense into four roughly discriminating areas; person, process, product and press. In the same lines Torrance (1965) attempts to classify the dimensions as:

(i) Newness as criterion
(ii) Creativity vs conformity
(iii) Creativity as a process
(iv) Creativity through the approaches of mental abilities.
(v) Levels of creativity, and
(vi) Approaches through the studies of creative persons.

Kneller (1965) observes, (i) creativity through the approaches of person may be considered in terms of physiology, temperament, personal attitudes, habits and values of the person who creates, (ii) explaining it by way of mental processes involves motivation, perception, learning, thinking and communicating the way, the act of creativity calls into play, (iii) Press implies understanding of creativity by focussing attention on environment and cultural influences, and (iv) products of creativity includes elements such as theories,
inventions, paintings, carvings, poems and the like.

To arrive at a meaningful picture of numerous definitions of creativity, all different views have been tentatively designed and presented in the same pattern as given by Gakhar (1975) within the roughly discriminating categories of product, process, person, and press.

(a) Creativity as a Product:

All types of creative products include an element of newness which implies novelty, freshness and inventiveness. In some definitions, newness has been viewed as tangible products but certain others believe that it can also be present in the intangible products. Rogers (1962) and Arnold (1962) include a poem, a work of art, or a scientific theory under tangible product. Mednick (1962) emphasize that such creative results must be useful. Likewise, Haefelo (1962) pleads that the creative innovations must have a social worth.

Dehaan and Havighurst (1961), remarked that creativity is the quality which leads to the production of something new, may be new to society or merely new for the individual who created it.

The creativity is compared with the problem solving ability by Harmon (1966). In the agreement of Harmon's viewpoint Mackinnon (1962) holds that creative response or idea is either novel or at the very least statistically infrequent
so that it helps to solve the problem. Creativity involves emergence in action of novel, rationale product, by the uniqueness of the individual (Rogers, 1954); whereas Piers et al. (1960) argues that novelty and usability of the creative product depends upon the capacity of an individual and unconventional ways of thinking and doing. Creativity, according to Mallory (1970) implies not making things complex, but making new forms.

However, Stewart (1950) assumes that the creative thinking may occur even though the idea produced may have been produced by someone already in earlier times. Also, productive thinking may take place in the mind of the humblest workman as well as in artist and scientist. According to him the importance of the creative product is to the individual and not the society.

A similar trend in the remarks of Thurston (1952) is there that it does not make any difference whether society regards an idea artistic, mechanical or theoretical as novel. Also too much emphasis on the social value of creative product is not appreciated by Guilford (1964).

Creativity is nothing but it simply involve the combination of old ideas and observations and information to form something that is new to us (Romey, 1975). Howely (1979) gives creativity as "the ability to produce new and valuable forms". So, creativity is the ability to generate novel concepts and either to know that they will work or find someone
who shows that they will work. Feedback, criticism and selectivity are the components of creativity.

(b) Creativity as a Process:

Creative thinking has been regarded basically as a process of seeing or creating relationship. This viewpoint can be emphasized by the various researches in the literature. Simpson (1922) defines creativity as the initiative which one manifests by his power to break away from the usual sequence of thought into an altogether different pattern of thought. This change of pattern of thought involves varying shifting approaches to a problem and selection of different elements so as to bind them together to tenable systems. Creativity is a process of change of development or evolution in the organization of subjective life (Ghiselin, 1958).

Torrance (1962) explains the concept of creativity as taking place in the process of sensing difficulties, problems, gaps in information, missing elements, identifying for difficulty, searching for solution, making guesses or formulating hypotheses about the deficiencies; testing these guesses and possibly revising and retesting them; and finally in communicating the results. Also, creativity as a mental process, thus seems to be purposeful and goal directed (Harmon, 1956 and MacKinnon, 1962).

Trowbridge (1978) states that "creativity depends on the balance between action, emotion and intellect, with the
addition of insight or intuition, and defined as the ability to synthesize the components of a situation into a meaningful whole". He has given the seven steps model for creative process; (i) awareness of need (motivation), (ii) preparation and study (intellectual activity), (iii) illumination (Insight or Intuition) (iv) appreciation of the solution (emotional reaction) (v) development of application techniques (Intellectual activity) (vi) implementation (action) and (vii) integration and assimilation. In an attempt to find out the role of creativity in scientific innovations, Brown (1977) studied numerous scientific breakthroughs. According to him each major advance in science involves an irrational, illogical element, a suspension of reason, together with a mental leap of creative insight.

Wallas (1926) identified four stages in the creative process: (i) Preparation, (ii) Incubation, (iii) Illumination and (iv) Verification. During the 'preparatory phase' the thinker is trying in a systematic and logical way to understand the problem before him and gathers as much information as he can. What actually happens during the phase of 'incubation' is obscure although, in theory, the unconscious mind is thought to take over and to continue to work upon the problem while the conscious mind is no longer actively considering it. This is a period of deliberate activity in search of evidence and solution but no conscious effort is made. It may be very short or very extensive period. At the 'illumination' there is the
sudden flash of insight, when a confusion of ideas suddenly takes shape. In the final stage, the stage of 'verification', the illumination is tested and retested to determine whether it solves the problem or not. This is the phase of active revision, expansion, and correction (Pioncane, 1952 and Vinacha, 1952).

(c) **Creativity Through the Approach of Person:**

There are various definitions which emphasize relevance of creativity with the cognitive and non-cognitive aspects of personality.

Many authors argue that creativity is related to unique cognitive factors (e.g., Guilford, 1950, 1957 and 1959), creativity involves the interplay of all the factors of divergent thinking. Creativity, according to him is by no means a unitary trait but, it is a collection of different abilities. There are so many types of thinking abilities (Guilford et al., 1951): (i) sensitivity to problems, (ii) fluency of ideas, (iii) flexibility (iv) originality, (v) redefinition, (vi) ability to rearrange, (vii) abstracting ability, (viii) synthesis, (ix) closure and (x) coherence of organization. Also, Torrance (1963) names the following factors in creativity, as: sensitivity to problem, ideational fluency, flexibility, originality, elaboration and redefinition.

So, there is a lot of controversy regarding creativity as Gordon (1961) and Koestler (1964) defined creativity as a
unitary trait. On the other hand McGuire et al. (1961), and Sultan (1962) have taken creativity as the complex human behaviour.

Creativity is also in accordance with cognitive qualities of personality. Freeman et al. (1963) has remarked that the difference in creativity, that is, high and low levels of creativity seem likely to be related more to non-cognitive than the cognitive traits.

Maslow (1959), through the approach of person, points out two senses of creativity, as (i) special talent creativeness and (ii) self actualizing creativity. He describes, that in the first sense, creativity can occur despite neurosis, but in second sense, it is the expression of sound and integrated personality.

MacKinnon (1962a, 1962b) and Barron (1965) have given the various personality traits of mathematicians and writers as the mathematicians were found to be individualistic, artistic, preoccupied, courageous, emotional and self-centered whereas, the artists were found to be possessing a high degree of intellectual ability and verbal fluency etc. Some of the personality characteristics of creative individual as given by Taylor and Holland (1964) are: autonomous, self-sufficient, independent in judgement, more stable, more feminine, self-assertive, more complex, more adventurous, emotionally sensitive, introvert, bold and self-controlled.

So, it is right to remark that creative talent are
unitary (Guilford, 1950 and Lowenfeld, 1958) but is linked with the intellectual ability and personality traits, as Dellas and Gaier (1970) conclude that creativity is a result of complex set of personality traits.

(d) **Creativity Through the Approach of Press**:

In order to support the role of environment (Press) in the creative process Halliman (1963) defines that the characteristics of environment both inner and outer, personal and social facilitates the person to move from the actual state of affairs which is possible towards the solution of problem and which is yet undetermined. In this light, Rogers (1954) also emphasized the role of environment and argues in favour of setting up conditions of psychological safety and psychological freedom to maximize the protruding out of creative rather constructive creative talent similarly - Torrance (1965) also emphasized the need of psychological freedom.

Likewise, in this group of environmental factors or socio-cultural factors, we can also gather the various factors such as social institutions and social practices, socio-economic status and the cultural sub groups etc. In another way, the creativeness is the function of certain professionals - such as artists, musicians and scientists etc. But Maslow (1962) identified certain persons as creative who did not belong to any category of professionals. Also, cultural environment may favour (activate) or inhibit the creative production (Cattell, 1906).
Various studies conclude that high creatives generally come from higher socio-economic group (Rivlen, 1959; Nuss, 1962, and Hudson, 1966).

According to Cropley (1973) the relationship between creativity and cultural forces is reciprocal. Similarly, Torrance (1973) emphasized that the cultural forces strongly influence the course of creative development the level of creative functioning that flourishes most.

So, at the end we can conclude the creativity is a complex attitude and newness, flexibility, originality and fluency are the main components of creative act. Also, creativity is a multidimensional ability Cattell and Butcher (1968) point out, "creativity is, in many respects, a vague term but it describes a quality or complex of qualities whose importance can hardly be exaggerated and it appears to be the best term for the wide spectrum of behaviour involved. That spectrum includes scientific discovery, artistic production, musical composition, technological invention, political and social innovation, literary creation and even religious leadership". A similar type of concept has been stated by Barron (1969) as, creativity may manifest itself in a variety of styles including not only the capacity to produce creative works oneself, but also the capacity to energise and crystallize creative efforts in others. Creativity also ranges across a wide variety of fields, so that it is necessary to take account of creativity in science, mathematics, engineering and similar fields, as well as artistic field".
While presenting an operational meaning of 'creativity' Wilson (1958) gave the diverse idea of creative process, as, "creativity is characterized by the outflow of individual or group through which a product is structured, an action of mind that produces a new idea, the mental process of manipulating the environment, the capacity to produce through imagination, the emergence of a novel rational product, growing out of the uniqueness of the person, the process which results in a novel work that is accepted as tenable or useful, and the process by which something new is produced - an idea or an object including a new form of arrangement of old elements. Also Jenson (1972) emphasized the multidimensional nature of creative process.

Recent studies have shown that creative behaviour is that type of a special behaviour which is shown in problems solving process. According to Davitz (1969) and others, "creative behaviour is perhaps a special class of problem solving".

1.4 SCIENTIFIC CREATIVITY:

One of the crippling obstacles in the path of development is the fact that quantity is almost more obvious, more visible, more conspicuous than quality. Whereas, in terms of achieving objectives in the long run, in attaining aspirations and in converting efforts into benefits, quality is often the crucial factor and that is lacking in our science education. The quality can be improved by the process of creativity, because, creativity constitute a subtle but absolutely key element in the building
of a scientific infrastructure.

As there is no universally accepted definition of creativity. Similarly, there is no fully agreed definition of scientific creativity. Bennett et al. (1969) who researched the meaning of creativity remarked that creativity is multi-faceted and does not mean something to all people. The meaning of creativity is fundamentally unclear. Though various definitions of creativity has been presented (Ghiselin, 1952; Stein, 1953; Lowenfield, 1958; Rhodes, 1961; Maslow, 1962; MacKinnon, 1962; Koestlar, 1964; Getzels, 1964; Guilford, 1968 and Gowan, 1972 etc.), but the most accepted definition of creativity is as given by Torrance (1967), in terms of process and the similar definition is equally useful in all areas like mathematics, science, language, social studies, psychology, music and physical education.

In the area of scientific creativity various authors have conducted research (Poincare, 1913; Coler, 1963; and Majumdar, 1973), it was emphasized that scientific creativity is creative thinking through the media of science. Coler (1963) while commenting on the creativity in science pointed out that creativity in different areas of human endeavour is as variegated as the discipline of the areas themselves in the following words: Although we have dealt with creativity as if it had a certain constancy, this too can be misleading. Despite the fact that we may speak of creative artists, writers and scientists in the same breadth, there is no strong evidence
that we are necessarily dealing with precisely the same phenomenon. In fact there are major differences. Thus, for example, mathematics, natural sciences and technology are cumulative, so that all prior work must be considered at least in principle. A contemporary creative writer may ignore or may not even be familiar with the works of Sphocles, a scientist cannot even complete his elementary education without utilizing the contributions of Euclid and Archimedes. Again although science is much more subjective and influenced by emotional and aesthetic factors, than is commonly realized, the explicity dominant role played by feelings, form of expression and style in the arts results in widely different bases of evaluation and preference ....... These fundamentals result in turn in differences in the type of personality that are attracted to the several fields of endeavour.

DeHaan and Havighurst (1961) and Sharma (1972) equated scientific creativity with problem solving type fact-finding activity.

MacKinnon (1963) has described that for the creation in the field of science, the environmental conditions, needs and goals are of paramount importance. The scientist operates on some aspect of environment in such a manner as to produce a novel or appropriate product. The most important aspect of scientific creativity is insight which helps the matrices of thought and create ideas in the fields. Rosca (1975) maintains that scientific creativity reflects not only a scientist's
ability but also needs of society and spirit of time, and that creative personality cannot be separated from its socio-historic context. Scientific creativity is becoming more and more associated with team work and should therefore, be approached from a socio-psychological point of view.

The process of scientific creativity involves systematic and logical approaches to the verification of results. The scientific creativity springs from truth and ends with truth. Three main objectives of science are: (i) to serve as a foundation for technology, that is, for the creation of processes, gadgets, procedures and prototypes with the aim of altering our environment to serve our desires and goals. This link between science and technology is generally recognised; (ii) to fulfil our general human aspirations which define the purpose of human lives. Among the countless such aspirations throughout the ages, we often find the thirst for understanding, knowledge, wisdom and for solving the countless such aspirations throughout the ages, we often find the thirst for understanding, knowledge, wisdom and for solving the countless riddles surrounding us. Particularly in this century, such scientific problem solving has become a hallmark of a "great" country of an "admirable" individual of a "respected" group. Material utility often figures in no way at all in the selection of such human aspirations; and (iii) to affect the view of man about the world and about his role in it. Much of our material progress and status depends upon the "Philosophical" outlook that underlines our attitude towards change, towards the extent to
which man can prevail over the often adverse condition he finds himself in. Science as a cultural force can have a great impact on such existential problems, as countless historical examples have demonstrated.

Based on these three main objectives of science, scientific creativity, therefore is an attribute that permits the infusion of new elements into any and all of these aspects and objectives of science. Thus, creativity can manifest itself in the conception of new ideas contributing to scientific knowledge itself, in the formulation of new theories of science, in devising of new experiments to probe nature's laws, in the development of the scientific ideas applied to the particular domains of practical interest, in the realization of new organizational features of scientific research and of the scientific community, in the novel implementation of plans and blue prints for scientific activities in trail blazing undertakings to transmit the scientific outlook into public mind and in many other realm. The common elements in all these channels is the establishment of something that was absent previously and which at the sometime significantly furthers the objectives of science referred to earlier.

On the basis of Torrance's definition of creativity, scientific creativity may be defined as, "a process of becoming sensitive to problems related to science, deficiencies gaps, missing elements, disharmonies and so on in scientific knowledge; identifying the difficulty; searching for solutions; making guesses or formulating hypotheses about deficiencies;
testing and retesting of these hypotheses and possibly modifying or retesting them and finally communicating the results." According to Moravcsik (1981), the scientific creativity means the attainment of new and novel steps in realising the objectives of science. What are these objectives?

These can be summarised into three main headings. All three hinges on the nature of science, that is, the human activity of producing new knowledge about the world around us. It is important to stress that the product of science is knowledge, that is, a rather intangible commodity which only after an additional chain of human activities is likely to turn into something concrete, something easily measurable, something that "down-to-earth" people like economists can deal with. Such knowledge about the world around us serves as the basis of the scientific creativity.

Operationally, scientific creativity may be defined as a multidimensional attribute distributed among people and includes the factors of fluency, flexibility and originality. Its measure is the scores on Scientific Creativity Test constructed and standardized by the investigator himself.

1.5 FACTORS AFFECTING SCIENTIFIC CREATIVITY:

There are various factors which are responsible for the development of scientific creativity among the students. According to Guilford (1980), "Determiners of scientifically creative production lie both within the individual and environment provided by his family, school, society and certain psychological stimuli". Creativity cannot be forced, it can
only be fostered. (Sandler, Taylor and Dorn, 1977). According to MacKinnon (1963) the environmental conditions, needs and goals are of paramount importance for the creation in the field of science. Stein (1963) has also emphasized the importance of good home environment in the development of scientific creativity. Informality and warmth of students, faculty contacts, closeness of supervision and directiveness of teaching methods have been found to be significantly correlated with creativity in science, the values of correlation were .43, -.38 and -.42 respectively (Thistlethwaitte, 1959). Kotarbinski (1968) too highlighted the significance of psychological, sociological and economic factors in the development of scientific creativity. Rasool (1977) well remarked that all of us are born with creative potential and if given proper environment, this potential can be recognized and nurtured. Also Chadha (1984) on highlighting the importance of good school environment in promoting scientific creativity among students remarked that creative development can be ensured if the dogmatic, authoritarian, restrictive and pedantic influences are removed from our schools. Such educational system has to be created which develops individual initiative, a spirit of enquiry, a taste for exploration and distaste for finality, a fearlessness for venturing into new ideas of action and thought. In such environment, creativity will take its own care.

Personality of the student is also one of the predictors of development of scientific creativity. Those individuals who
are highly intelligent, preoccupied with tasks, independent, enthusiastic, introspective, skeptical, precise, reliable, self-sufficient, dominant, emotionally sensitive, courageous, self-centered, imaginative, more stable, more feminine, more resourceful, introverted and bold are considered to be scientifically creative individuals (Cattell, 1954, 1959, 1968; Cattell and Drevdahl, 1955; Drevdahl, 1956; MacKinnon 1962; Barron, 1965 and Taylor and Holland, 1964). The significant differences in the levels of intelligence of both scientifically creative and non-creative groups were found by Jhaj (1983), showing the variable of intelligence as an important predictor of development of scientific creativity. A little importance of intelligence in the development of scientific creativity among students is found by Grewal (1974). Also, the cognitive styles highly influence the scientific creativity development (Lloyd, 1978; Anna, 1982 and Musil, Miroslav and Ondrusek, 1982). Strauss and Strauss (1958) determined that sex differences are also significant in the development of scientific creativity. The area, in which the school or college is situated, is an important factor in the development of scientific creativity (Shukla and Sharma, 1986).

So, keeping in view the above given factors which are helpful or inhibitor in the development of scientific creativity among the students, the present problem has been considered worthwhile by the investigator to explore this field further.
1.6 OPERATIONAL DEFINITIONS OF THE TERMS USED:

In order to ensure clarity and precision in the discussion part, it was thought necessary to present the operational definitions of the various terms used in the present study:

1.6.1 Intelligence:

Intelligence is the general adaptability to the new problems and conditions of life, as explained by Stern (1914). According to Wesman (1968), intelligence is what has been learnt. But, the fact that intelligence is a summation of learning experiences, implies that intelligence tests do not measure an ability or potentiality as much as they do measure achievement. There are some people who are very poor on the intelligence test score, even then they are well adjusted in life and are aware of many general facts. Whereas, the persons who show good scores on the intelligence test are unaware of common knowledge and are maladjusted. So, various definitions of intelligence have been given by different educationists and psychologists. Operationally, intelligence is defined as, "the ability to deal with numbers, analogies, opposites and synonyms, to make categories and to draw inferences". Its measurement (verbal) is the total score on Group Test of General Mental Ability (Jalota, 1987).

1.6. Personality:

The term 'Personality' has been derived from Latin word 'Persona', which means 'to sound through'. By personality
it is now generally meant that it is the organization and integration of a large number of human traits. The concept of personality differs widely among different people. Some people consider it as inborn character, the other people regard an individual's personality as a person himself.

Operationally, the personality is defined as that, which permits a predication of what a person do in a given situation and is concerned with all the behaviour of the individual both over and under the skin (Cattell and Eber, 1967). The scores obtained on 16 Personality Factors Questionnaire, by Cattell and Eber (1967), are the measures of personality.

1.6.3 Cognitive Styles:

Cognitive styles refer to the modes on individual employee in perceiving, organizing and labelling various dimensions of the environment. The construct applied in the present study is "Field-independent and field-dependent" trait. A person with field independent way of perceiving tends to experience his surroundings analytically, with objects as discrete from their backgrounds. The person with field-dependent way of perceiving tends to experience his surroundings in a relatively global manner, confirming to the influence of prevailing field.

Operationally, cognitive style implies the habitual pattern or preferred strategy of information processing. Its measure is the scores obtained on Group Embedded Figures.
1.6.4 Environmental Catalysts:

The environmental catalysts consist of emotional, physical and intellectual climate that is set up by the parents, teachers and students, which stimulate the teaching and learning process. In the context of Teacher Education Programme, Ahluwalia (1970) used the term as, "the nature and extent of change in the professional attitude of students-teachers, which is perhaps catalysed by Teacher Education Programme."

Operationally, these are the factors present in the environment, which affect the quality and quantity of learning done by the students. These factors can be home environment, school environment, personal attributes, society and psychological environment.

1.6.5 Sex Differences:

All males differ from all females on the traits, abilities and behaviour, that we have come to call sex difference. According to Geddes and Thompson (cited by Shields, 1975), the males are 'catabolic' and females are 'anabolic'. This biological difference between men and women was thought 'naturally' to lead such things as greater agility, creativity, variability and scientific insight for men and greater patience, open-mindedness, appreciation for subtle details and intuition for women. But, in many areas in learning, hardly any differences are found in the learning abilities of boys.
and girls. The girls, on the part dealing with linguistic ability score higher than boys and on the mathematical part boys score better.

1.6.6 Urban and Rural Areas:

Urban denotes a distinct quality of human community, a special mode of existence or way of life which is characteristic of the city. A society or community may be defined as rural which has less population, less social differentiation, slower rates of social change and agriculture as a major occupation.

In the present study, the samples are drawn from both urban and rural communities. The role of rural and urban environment in accelerating scientific creativity is of paramount importance. The students belonging to the urban community are generally good at the scientific skills. This is perhaps due to the reason that in the cities, there are facilities for fostering the development of good education and practical work. But in rural communities, science education is provided only as a dull subject. There is lack of practical work and activity in science education resulting in the poor development of scientific creativity.

1.7 Emergence of the Problem:

It was only during the past centuries that we neglected science and scientific research. The decay of Indian science roughly began from 15th century. The political confusion created and maintained by foreign invasions,
internal troubles and the disinterest shown by rulers can be the general reasons for this tragic decay. It is interesting to note that the decay of science marked the decay of Indian society too. But, the attainment of independence marked a change in National Science Policy. The various commissions and committees appointed by government of independent India have given the stress on the importance of science teaching and the advanced research in science education. As given by Kothari Education Commission (1952-53), "the basic approach and philosophy underlying the reconstruction of education adopted by us in this report rest on our deep conviction that the progress, welfare and security of the nation depend critically on a rapid, planned and sustained growth in the quality and extent of education, and research in science and technology". Today, we cannot think of world without the knowledge of science. In Gallants' words, the most conspicuous aspect of our civilization today is the pervasive and remifying impact of science in every department of life, from household management to warfare. But, there is no use of writing these ideas and plans in paper, rather we have to implement these ideas in a practical way.

The present day situation is very critical. To carry out research in science and technology, we have to develop the minds of children with scientific outlook; that is, to develop scientific interest, scientific attitude, problem solving ability, methodology of research, scientific thinking and scientific creativity.
Out of the above areas, the researcher considered it worthwhile to study the scientific creativity among students in order to encourage their problem solving ability. This factor is highly influenced by intellectual level of the individual, his personality, style of perceiving things, sex and certain environmental factors etc. So, there is a need to identify various factors which really go with the scientific creativity. Hence, the present investigation studies the scientific creativity of the students in relation to their intelligence, personality, cognitive styles, sex and selected environmental catalysts.

1.8 STATEMENT OF THE PROBLEM:

A great need of research in the field of scientific creativity is felt due to the scientific advancement in the present age. Today the aim of education is to develop right type of scientific attitude among the students right from their schooling. There are various factors which go with the development of scientific creativity among students. Some of these factors are intelligence, personality, cognitive styles and certain selected catalysts of environment. So, in the light of above given factors, the problem for the present study has been stated as,

"Scientific Creativity in Relation to Intelligence Personality Cognitive Styles and Selected Environmental Catalysts"
1.9 OBJECTIVES OF THE STUDY:

The present study was directed towards the following objectives:

1. To construct and standardize 'Scientific Creativity Test'.

2. To construct and standardize 'Environmental Catalysts Scale'.

3. To study and compare the relationship of intelligence, personality, cognitive styles and selected environmental catalysts with scientific creativity of the urban and rural students.

4. To examine and compare factorial structure underlying the variables of intelligence, personality, cognitive styles, selected environmental catalysts and scientific creativity of the urban and rural students.

5. (a) To study and compare the predictive efficiency of the variables of intelligence, personality, cognitive styles and selected environmental catalysts in predicting the criterion variable of scientific creativity.

(b) To examine the conjoint effect of intelligence, personality, cognitive styles and selected environmental catalysts in predicting the criterion variable of scientific creativity of urban and rural students.
To study the differences in scientific creativity in relation to different levels of intelligence, cognitive styles, sex, Environmental Catalysts for both the samples as well as their area-wise differences.

1.10 **DELIMITATION OF THE PROBLEM:**

While applying generalizations of the study as reported towards the end of the report, following limitations were kept in mind.

1. The study was delimited to 500 students of XI Class.
2. The investigation was delimited to schools and colleges of Punjab state only.
3. This study was delimited to the sample drawn from both urban and rural population.

1.11 **NEED AND SIGNIFICANCE OF THE STUDY:**

Creativity in science has been of vital importance in promoting the progress of human civilization. Science is nothing but creative thinking and creative doing. But our educational system provides no direction to the creative domain of the child and so many creative talents are left in seedling form. It is well remarked by Flescher (1963) that, "the cultivation of creative potentiality has been largely neglected by education." Our academic education is mostly anticreative. The unchallenging classroom activities fail to inspire the scientific creativity among the students. Lack of creativity besides causing poor adjustment of the individual and group
tensions may annihilate the world. Without creative people we cannot think of a well developed society. Therefore, a great need is there to explore this field of scientific creativity.

Eversince, the research has been started in the field of creativity, it was realized that in order to extend the frontiers of knowledge, the research in the field of scientific creativity is very important. There have been found a large variety of studies in the field of general creativity conducted by some researchers in India as well as in abroad. (e.g., Raina, 1971; Goyal, 1973; Gakhar, 1975; Torrance, 1973; and Trowbridge, 1978), but there is paucity of research in the field of scientific creativity as compared to the other areas of education. So, in the light of this point of view, there is need to enrich the content and subject matter of scientific creativity.

The importance of development of scientific creativity in this atomic age also itself is contributory to accelerate the pace of research activity in scientific and other fields of life, and scientific creativity is helpful in the scientific and technological advancement of the country.

Mohsin (1963) in his Presidential address to VIIIth All India Guidance Conference held at Allahabad, stated, "society consists of individuals. But it is only few exceptionally talented individuals who contribute to the most of the growth of society. They create new horizons and set
new standard in science, technology, literature, business, industry and social leadership. No sooner does society become devoid of nature's gift of talents, it would start to stagnate and ultimately perish."

Since the progress of whole nation depends highly upon the man power especially the creative personnel, therefore, this is the responsibility of our teachers and educational system to develop the creative talents of the children. The purpose of education is also to develop abilities and potentialities, personal expression, gifted leadership and ultimately preparation for practical life and this cannot be possible without the development of creativity in science. So, this study will have far reaching implications for the pedagogy of teaching and learning.

This study when completed would reveal significant trends as to the degree and extent of predicability and relationship of intelligence, personality, cognitive styles and selected environmental catalysts with scientific creativity and thus will motivate and encourage educationalists and curriculum framers to design academic experiences in a way that these will help to foster the development of scientific creativity among the students right from the school stage. This will also be helpful in the development of scientific creativity in accordance with students' abilities, personality learning and cognitive styles and their home, school or psychological environment.
Of fundamental significance is the realization of individual's creative potential they possess, and to provide environmental conditions conducive to its development. Creativity, as Murphy (1966) maintains does not just happen. It needs appropriate seed, soil and climate. Now to identify creative individuals and foster creative abilities are the most crucial questions in the investigation of creativity. In this line, the findings of the present study will be helpful for the teachers to identify creative talents of the students in science. Mostly the teachers get failed to identify them due to the reason that they have inadequate knowledge and understanding of the creative process, and lack of knowledge of factors which inhibit and accelerate the development of scientific creativity. Thus, from the present findings, the teachers can inspire the students to develop scientific creativity, keeping in mind their abilities, personality, cognitive styles and role of environmental catalysts in promoting scientific creativity. Accordingly, they can inspire and nourish the future scientists by providing good and congenial environment, since creativity can be fostered and not be forced.

On completion, the present study will provide standardized tool, that is the Environmental Catalysts Scale for assessing the role of catalysts of environment in developing the scientific creativity among the students. It is well remarked that people seem to possess the seeds of creativeness but climate for its germination is absent. It is very true
if we compare the scientific creativity to human embryo. If soon after conception, embryo is not identified and left to develop itself, it will perish as a result of failure to adopt to adverse circumstances. But if congenial atmosphere is provided, it will hatch and develop. Similarly, in order to develop scientific creativity and encourage creative talents we have to provide congenial atmosphere for students; so that they may not go on the road of delinquency, a life of mediocrity and distress. The standardized Scientific Creativity Test can help the teachers to identify the talented and creative talents and to prevent a great loss to nation.

The findings of the study can also be helpful for the counsellor because after having identified creative science students, the counsellor by the group technique of guidance can explain them that stimulation of home and school environment and their positive personal attributes can foster and encourage scientific creativity in them. Also, parents from the findings of the present study can understand what their children expect from them, what are their abilities and what kind of environment should be created for them, so that the creative talents in science must be flourished.

Further, one's intelligence, personality, cognitive styles and environmental catalysts play important role in the development of scientific creativity. The findings of the present study will not tell only the relationship of scientific
creativity with intelligence, personality, cognitive styles and selected environmental catalysts by using single variable approach which gives distorted picture of the relationship between different variables but will tell the conjoint predictive efficacy of different variables in predicting the scientific creativity of the students.

National Policy of Education (1968) has also emphasized to make changes in the content and methodology of teaching and learning of science, in order to prepare the man power to use modern technology. Moreover, no nation can afford to neglect the scientific creativity of its children, if it has to make its identification or even to make its existence in the modern rapid scientific technological advancement in the world, as creativity is the basis of all social progress and technology.

So, encouraged by these considerations, the investigator chose this field of scientific creativity for further explanation.

1.12 ORGANIZATION OF CHAPTERS IN THE REPORT:

The introductory chapter of the report presents the need, emergence of the present problem and operational definitions of the predictors. Various theoretical viewpoints regarding intelligence, personality, cognitive styles and environmental catalysts have been discussed in the second chapter, while the third chapter deals with the review of related literature. In the fourth chapter, methodology and
procedure along with the detailed account of the research tools used for the present study has been given whereas the fifth chapter has been devoted for the development and standardization of Scientific Creativity Test. In the sixth chapter, the detailed description of preparation and standardization of Environmental Catalysts Scale has been presented. Seventh chapter studies the nature of score distributions. Eighth chapter accounts for the analysis of data, discussion and interpretation of results. While the summary, conclusions and suggestions for further research form the content of ninth chapter.

Bibliography and Appendices, as usual, have been given at the end of the Research Report.