CHAPTER I
INTRODUCTION

In recent years, identification and promotion of creativity among school children is receiving greater attention in different countries including India. This ever-growing concern for talent identification has resulted in greater research activities in the area of creativity - its meaning, nature and measurement. Of late, creativity in mathematics has emerged as a separate field of research. Research in this area has focused attention on the characteristics of mathematically creative children, teaching strategies, classroom learning environment and a host of other related factors conducive to the promotion of pupil creativity in mathematics. In our country, however, not much has been done to foster pupil mathematical creativity.

Several reasons may be attributed to the neglect of creativity in mathematics in our educational institutions. Firstly, discoveries and inventions in mathematics are not as frequent as in sciences and performing arts and this probably is responsible for the low status of creativity in mathematics. Mathematical creations, such as formulation of new concepts, theories and principles are, however, in no way inferior to creative work in literature, music, painting, science etc. Scientists have made use of mathematical theories and principles discovered earlier in the interpretation, prediction and control of natural and social phenomena for purposes of solving societal problems. Thus, down the ages, creative mathematics has
made significant contribution to the advancement of human culture and civilization. In the modern world, creativity in mathematics is in great demand for warfare too. As Fadiman (1957) has observed, "Mathematics is part and parcel of modern war, not merely in the gross concerns of ballistics, but in the subtler ones of strategy and tactics". Mathematical inventions help the discovery of new strategies not only for annihilation of the enemy but also for self-protection against any attack.

Secondly, misconception about the nature of creativity may be a potent cause for the indifference in promoting creativity in mathematics at the different stages of education. The ideas that 'creativity is a gift of God or Nature' and that 'creative abilities are bestowed upon a few blessed individuals' are deeply ingrained in our teachers and these notions make them insensitive to the reality that education can encourage and develop creativity, although it cannot create it (creativity) (Burt, 1962). In fact, recent research shows that creativity is not restricted to a chosen few and that it is a universal endowment of humanity. Arieti (1976), for instance, has observed that, "Creativity, a prerogative of man, can be seen as the humble human counterpart of God's creation". As to the 'nature' or inheritance of creative abilities, opinions are, of course, diverse. While Galton's (1869) study of men of genius, who were
selected from nine different fields of achievement, made him entertain the notion of heritability of mental abilities. Pezzullo et al. (1972) observed no evidence for the heritability of creative thinking abilities. Matussek's (1974) study also found that creativity is not only independent of inherited talent, but also of environment and upbringing. For him creativity "is the function of the ego of every human being" (Arieti, 1976). Guilford (1952) believed that creative activity tends to represent to some extent many learned skills, which may be limited by heredity, but within the limitations set by heredity, these skills can be developed through learning. Subsequent findings (Taylor, 1959; Maltzman et al. 1959; Meadow and Parnes, 1959; Parnes and Meadow, 1959; Parnes, 1961; Sommers, 1961) have supported Guilford's views. Creative behaviour is likely to increase if the skills of creative thinking are taught in schools under appropriate conditions (Torrance, 1930). Creativity can be developed through using creative strategies in the teaching of different subjects. Mathematics affords enough opportunities for promoting creative thinking abilities. Mathematical creativity has to be stimulated. Osborn's (1953) 'brain storming' technique and Gordon's (1961) 'synectics' technique have proved useful in promoting mathematical creativity among school children. Creative instructional materials, teaching procedures, and learning environment are found to influence children's mathematical creativity.
Thirdly, there is the tendency to underestimate the quality of mathematical creations of pupils and this has contributed its share to the lack of interest in creativity in mathematics at the school level. Educational planners and administrators in India are probably under the impression that school children cannot produce creative work comparable to those of great mathematicians even if adequate provisions for training are made by schools. There are, however, instances of mathematicians who had produced well-known mathematical theories, principles etc. when they were quite young in age. Pascal, for example, was only sixteen when he formulated the theory of triangular pattern, known as "Pascal's triangles". At the age of nineteen, Gauss started making brief notes of his mathematical discoveries, the first of which refers to a method of inscribing a regular septagon in a circle. Galileo and Einstein were teen-agers when they presented their unique discoveries in mathematics and physics. If these instances are considered as exceptional cases rather than the general phenomena, it may be pointed out that for the large majority of our school children outstanding creative work in mathematics requires "a level of skills that can be acquired with years of experience and training" (Roedell et al. 1980). It is, therefore, imperative on the part of school authorities to identify whatever mathematical creativity is present in individual students and to nurture it through appropriate training programmes. Such provisions for training would at least enhance the
students' capacity to think creatively in mathematics, if not enable every student to create something or other in the area of mathematics. Guilford (1980) aptly wrote, "If every member of the human family could be made even a little more creative, in summation the benefits could be tremendous".

Finally, confusion over the meaning of creativity in mathematics appears to be the most important cause for the indifference towards training of pupils in mathematical creativity. In fact, definitions of creativity in mathematics, like those of creativity, do not connote a clear-cut meaning of the construct. Those, who are concerned with secondary education, are, therefore, at a loss to decide what exactly should be aimed at in fostering creativity in mathematics at the school stage. A careful examination of definitions of creativity in mathematics would make this point clear.

1.1 Creativity in Mathematics (Mathematical Creativity): Its meaning

Authors and researchers, who have tried to define 'creativity in mathematics', have focused their attention on different aspects of this complex phenomenon. There are three approaches - Product, Process and Trait approaches to the definition of mathematical creativity. These approaches together with examples of definitions are given in the following sub-sections.
1.1-1 Product Approach: The product-oriented definitions of creativity in mathematics emphasize the discovery of new and socially useful concepts, theories, principles or novel methods of solving mathematical problems as the criterion of creativeness. These definitions are similar to those proposed by Drevdahl (1956), DeHann and Havighurst (1957), Maslow (1959), Rogers (1959), Haefele (1962) and Jackson and Messick (1964) for the definition of the term 'creativity'. The French mathematician Henry Poincare (1924) brought forward his views on mathematical creation when he said, "It does not consist in making new combinations with mathematical entities already known ............... To create consists precisely in not making useless combinations and in making those which are useful and which are only a small minority". Carlton (1959) maintained, "Creative thinking is thinking which results in addition to knowledge". To Romey (1970), "Creativity is the ability to combine ideas, things, techniques, or approaches in a new way". Tuli (1982) believed that mathematical creativity expresses itself in generating new significant concepts, generalizing a number of concepts and theorems, and establishing relations among facts of mathematics and facts of nature and society.

Certain operational definitions of mathematical creativity have also been formulated in terms of production of unusual but applicable responses or solutions to
mathematical situations. Spraker (1961), for instance, defined creativity as "the ability to produce original or unusual, applicable methods of solution for problems in mathematics". Jensen (1973) conceived mathematical creativity "as the ability to give numerous, different and applicable responses when presented with a mathematical situation in written, graphic or chart form". For Lee (1979), mathematical creativity is "an ability to go beyond the common place and ordinary in mathematics, an ability to combine mathematical information and/or experience in a unique and insightful manner".

1.1-2 Process Approach: In this approach thought process leading to mathematical invention rather than the invention itself has been emphasized as crucial to the study of creativity in mathematics. Poincare (1924) was the first to give a lucid and vivid account of the discovery process in mathematics. Mathematical invention, according to him, involves useful and novel combinations of familiar mathematical entities. Such combinations emerge from the unconscious or subliminal self. Poincare recognised the significant role of unconscious processes in mathematical creations when he observed; "The role of this unconscious work in mathematical invention appears to me incontestable, and the trace of it would be found in other areas where it is less evident". This was latter corroborated by Psychoanalytic views of Freud (1959) and Jung (1959).
Poincare has proposed two hypotheses to explain the role of the unconscious mental processes in mathematical creations. His first hypothesis states that a mathematician who is confronted with a difficult problem attempts to solve the same through deliberate, conscious, persistent and sincere efforts. When the problem does not get solved he gives up the deliberate attempts and relaxes. But at the unconscious level certain mental processes take place and several combinations of ideas arise and collide and the individual has no control over these. When the right combination of ideas leading to the solution of the problem appears, it strikes the conscious resulting in "sudden illumination". The second hypothesis is based upon the assumption that all the elements or ideas to be used in making mathematical combinations are "atoms" hooked to the mind's wall and remain motionless during the period of complete rest. During the period of apparent rest and unconscious work a few of them are mobilized to form different combinations of ideas and one of these leads to the desired solution.

Poincare, too, divided the creative process in mathematics into four different stages, and analysed the mental activities involved in each stage. The first three stages are almost identical to those proposed by Helmholtz (1896), whereas the fourth one is an addition to those of the latter. These stages in the creative process in
mathematics are briefly described below.

1) A Period of Conscious Work or Voluntary Effort: This is the stage when the creative mathematician makes the first attempt at solving the problem. He toys with different mathematical ideas, facts and principles; tries out different approaches to the problem; but being unsuccessful in discovering the desired solution, gives up his attempt for sometime. In short, this is the stage of "an initial investigation carried on until it is impossible to go further" (Helmholtz, 1896). These initial efforts, although appear fruitless, make the unconscious mind active.

2) A Period of Apparent Rest: During this stage the mathematician makes no efforts at the conscious level to reach the solution. It seems as if he has given up working on the problem and is enjoying complete rest. In fact, this is the period of apparent rest when the unconscious mind tries different ideas and makes tentative solutions. Intuition of mathematical order helps the unconscious in divining hidden harmonies and relations among mathematical elements.

3) Appearance of a Sudden Illumination: The new idea or the desired solution reveals itself to the mathematician all of a sudden at this stage. This sudden "illumination" or "inspiration" is the culmination of a series of tentative solutions formulated by the unconscious mind.
4) A Second Period of Conscious Work: This is the stage when the mathematician puts the results of the sudden "inspiration" in shape, deduces immediate consequences from those results, arranges them, describes the demonstration in words, and, above all, verifies the results through conscious efforts. He follows the same series of mathematical and logical rules as were used in controlling the initial conscious efforts.

Poincare's account of the creative process in mathematics has provided the basis for formulation of definitions of mathematical creativity. Hofh (1961), for instance, held, "the mathematician's primary creative activity is the study of patterns, relationships, forms and structures in the system of numbers, geometrical figures, functions and other subjects of interest". He has emphatically stated that the mathematician should look for forms and structures not only in the world of numbers and geometrical figures, but also in disparate fields, such as biology, physics, chemistry, agriculture, psychology and many others.

In Laycock's (1970) view, "Creative mathematics is not that mathematics that asks only correct answers .... It is the ability to analyse a given problem in many ways, observe patterns, see likenesses and differences, and, on the basis of what has worked on similar situations, decide upon a method of attack in an unfamiliar situation".
Singh (1981) conceived of mathematical creativity as a process of generating new significant ideas, making theoretical ideas practical, converting innovative ideas of other fields into this field. For Chitriv (1982), "Creative process in mathematics is nothing but the conquest of intuition. .... Groping, blundering, conjecturing, hypothesizing on an adventurous path of mathematical creation are all guided by intuition. Imagination, divination, and insight are but its twin sisters.

These process-oriented definitions of mathematical creativity resemble the definitions of general creativity suggested by Torrance (1962), Mac-Kinnon (1962), Mednick and Mednick (1964), Parnes (1967) and others.

1.1-3 Trait Approach: This approach to creativity in mathematics involves identification of different intellectual and non-intellectual factors governing mathematical creativity. In other words, the focus of this approach is to list the different traits of creative mathematicians and look for such traits in individuals who are alleged to be creative in mathematics. Accounts of some creative mathematicians about their own experiences in mathematical creation and factor analytic studies have revealed many intellectual abilities and non-intellectual personality factors conducive to mathematical creativity.
Poincare, on the basis of his own experience in mathematical creation, believed that a creative mathematician should, no doubt, have reasonable degree of memory power, strong will, absolute conviction, power of attention and emotional sensibility. What is more important than these qualities is the feeling of 'intuition'. To emphasize the significant role of intuition in mathematical creation, he has observed that those who possess this 'intuition' in less or greater degree can not only understand mathematics even if they do not have extraordinary memory, "but may become creators and try to invent with more or less success according as this intuition is more or less developed in them".

Creative mathematicians appear to think creatively on the images of concrete objects and figures. In fact, Hadamard (1945) himself has reported that visual pictures were the means of his creative thinking. Roe (1952) and Walkup (1967) also reported that scientists used "Visual imagery" in their creative thinking.

Factor analytic studies have shown that deductive and inductive reasoning, numerical, spatial-perceptual abilities and verbal comprehension are the essential components of mathematical ability. (Aiken, 1973).

On the basis of logical analysis of the responses of Russian children to mathematical problems, Krutetskii (1966) has suggested a classification of the components of mathematical ability. These components include (i) formalized
perception of mathematical material, (ii) generalization of mathematical material, (iii) curtailment of thought, (iv) flexibility of thought, (v) striving for economy of mental forces, (vi) mathematical memory; and (vii) spatial concepts. He has also confirmed Poincare's observation that good memory, computational skill and verbal fluency may not always be found with good mathematicians (Aiken, 1973). It is, therefore, believed that these abilities have their place in the creative thinking of mathematicians.

Guilford (1980) has viewed all episodes of creative production as problem-solving events, and distinguished between more creative and less creative problem-solving episodes in terms of the degree of novelty and ingenuity involved. He has developed a problem-solving model, called The Structure-of-Intellect Problem-Solving (SIPS) Model. This model shows that all the mental operations included in his 'Structure-of Intellect (SI) Model' are also involved in the problem-solving process at some stage or the other. The SI model includes five mental operations, viz. cognition, memory, divergent production, convergent production and evaluation, and these play a significant role in creative production or problem-solving in any field of human endeavour.

The abilities involved in cognition help the individual to recognise the problem, sense the incongruencies, gaps or
missing elements in the problem situation. They also very often facilitate the formulation of creative problems. Problem-formulation demands a clear conception of the problem situation, and involves search for patterns, facts or information. The conception of the problem is as important as its solution. Getzels and Csikszentmihalyi, (1964) aptly stated that "the significant element in creative performance is the envisagement of the creative problems for it is the fruitful question to which the novel solution is the response". Reed (1957), too, echoed the importance of problem formulation when he wrote, "Problems become the mainspring to creative thinking. Without a problem to solve, the child has no motivation to think originally".

Memory abilities make indirect but important contribution to creative production in that, both in structuring the creative problem and searching for a novel solution, the creative problem solver has to retrieve information from his memory store. A creative mathematician's memory may not be as good as a computer, but it should be good enough to facilitate identification of correct pattern, relationship, form or structure of the mathematical elements, and production of tentative solutions.

Divergent thinking or divergent production abilities play a key role in creative problem-solving. At the stage of problem-formulation, these abilities facilitate the
scanning of several concepts from the stored information to determine the cognitive structure of the problem. At the problem-solution stage, they enable the creator to generate a number of varied and different items of information or useful tentative solutions to the problem. Divergent production abilities, such as fluency, flexibility, and originality are as important in the creative productions in mathematics as in other fields. Fluency which is defined as the ability to produce a number of fertile ideas or hypotheses is important in mathematical creation. When the data provided in the problem do not readily lead to a solution, the individual thinks of other ideas or possible solutions. In fact, many mathematical problems, which require novel solutions, demand what Guilford calls "ideational fluency". Flexibility which is usually defined as the ability to produce different categories or classes of ideas is no less important in creative problem-solving. Flexibility, rather than rigidity, characterises creative problem solving. Like-wise, originality which is defined operationally as the statistical infrequency of a response is the most important ability which determines whether the idea, theory, principle or procedure can be called creative or otherwise.

In contrast to divergent thinking, convergent thinking involves the ability to produce a single answer appropriate
for the specifications of the given problem. In other words, it is the ability to do "focused search" or "search for logical imperatives".

Evaluation abilities are concerned with critical thinking and judgement. In mathematical creative problem-solving the mathematician has to depend upon these abilities. They help him decide whether a real problem exists or not, determine the worthwhileness of the problem, structure the creative problem, formulate useful hypotheses, accept the correct solution(s), and reject others.

In addition to these five categories of mental operations, the transformation abilities in the product category of the SI model have a significant role in creative problem-solving. These abilities provide for the flexibility needed both at the cognition and production stages. According to Guilford (1980) divergent production and transformation abilities "have the most apparent connection with creative processes and creative disposition".

1.1-4 Synthesis of Different Approaches: None of the preceding view-points on creativity in mathematics is free from criticism since each overlooks the important characteristics included in the others. However, a synthesis of different view-points suggests a three-fold
criteria of mathematical creativity. First, a mathematician to be called creative must invent a new theory or principle or a novel method of solving a mathematical problem, which will extend knowledge of the mankind or of the person concerned. Second, he must be able to formulate a creative problem, conjecture and develop tentative solutions, principles or theories through study of patterns, forms and relationships in disparate fields, verify those tentative solutions and communicate the accurate results in an organised form. Third, he must be willing to take risks in trying out uncommon ideas or methods, besides being persistent in his efforts.

1.2 Measurement of Creativity in Mathematics:

It is often pointed out that the creative process is basically the same although the creative product is content specific in the sense that it may relate to mathematics, sciences, art, architecture, music or other areas. Kundley (1982) has pointed out, "every field of creativity has its own modality, and creative production in each field would need specific mode of thinking, and other prerequisites". For instance, literary creativity demands a great deal of linguistic abilities, but little numerical, figural or other abilities, while the demand of scientific creativity is just the opposite; and none of these
abilities is essential for creativity in painting or music. Due to such differences in the abilities involved in different fields of creativity very few individuals have succeeded in producing creative work of equal standard in disparate fields. Gropely (1980) aptly said that "Creativity also ranges across a variety of fields, so that it is necessary to take account of creativity in science, mathematics, engineering, and similar fields, as well as artistic fields". These considerations lead to the notion that creativity in mathematics could be assessed through tests calling for divergent thinking abilities in mathematical situations.

Over the years tests have been developed for the measurement of creative abilities in mathematics, but these tests have not received public attention. Most of these are research editions and are not commercially available. These are mostly designed for use with school children in evaluating their creative abilities in mathematics rather than real life creativity in this field.

1.3 Criteria for the Construction of Mathematical Creativity Tests:

Two criteria have been used in developing creativity tests in mathematics. Some authors like Prouse (1965, 1967) and Balka (1975) have accepted both divergent and convergent production abilities as the criterion measure.
of creativity in mathematics. They have grounded their tests on the assumption that mathematical creativity is manifested in these two kinds of abilities. Open-ended mathematical problems with moderate structures are incorporated in these tests to measure divergent production abilities. The items included in these tests require the subjects to produce as many varieties of correct responses as they can within the stipulated time. These tests also included multiple choice type items for assessing convergent thinking abilities. Other creativity tests in mathematics lay emphasis on divergent production abilities alone and consist of only open-ended items.

The rationale for using this type of tests as predictors of creative potentiality in this area may be found in Crockenberg's (1972) statement; "A number of distinguished people from the arts and sciences have mentioned the free flow of ideas as a crucial stage in the creative process; therefore, it is reasonable for psychologists interested in the creative process to use the productive ideas as a measure of this process". Guilford (1980), too, has observed that the operation of divergent production has the most obvious connection with creative thinking.

Several criterion behaviour of potentially creative problem-solvers, identified from previous research studies and pre-validated by competent educationists, have provided the basis for construction of creativity tests in mathematics (Prouse, 1965; Meyer, 1970; Balka, 1975).
Some of these criterion behaviours are:

(i) Ability to formulate mathematical hypotheses concerning cause and effect in mathematical situations.

(ii) Ability to determine patterns in mathematical situations.

(iii) Ability to break from established mind sets to obtain new solutions to given or conceived mathematical situations.

(iv) Ability to consider and evaluate unusual mathematical ideas, to think through their possible consequences for a mathematical situation.

(v) Ability to sense needed missing elements or gaps in existing mathematical knowledge and to ask questions that will enable one to fill in the missing elements or gaps in mathematical information.

(vi) Ability to break general mathematical problems into specific sub-problems.

(vii) Ability to generalise particular results either by finding common threads of induction or by determining patterns by analogy in mathematical situations.

(viii) Ability to find relations among various parts of the problem situation and focus these towards unique solutions.

1.3.1 Procedures used in the Measurement of Mathematical Creativity: Two different procedures - testing and rating - have been employed in the measurement and evaluation of creativity in mathematics. Getzels and
Jackson (1958) included a test item, which required to make mathematical problems from the given data, in the creativity test battery designed by them to obtain measures of creativity for their study of "the Highly intelligent and Highly creative adolescents". Later, Spraker (1961), Banghart and Spraker (1963), Evans (1965), Prouse (1965, 1967), Buckeye (1968), Foster (1970), Baur (1971), Mainville (1972), Baka (1975) and Zosa (1978) joined the testing movement and made valuable contributions by developing separate tests or test-batteries for measuring mathematical creativity. In India, Singh (1981) and Acharyulu et al (1981) constructed their own tests of mathematical creativity, whereas Tuli (1982) translated Baka's 'Creative Ability in Mathematics Test' into Hindi for research purposes. All the instruments referred to above are non-commercial paper-pencil tests and are administered to groups of subjects.

Creative ability in mathematics has also been evaluated through rating the behaviour of individuals engaged in the creative process. Meyer (1970) used this technique in his study using six criteria. Five of these describe observable activities in which most pupils engage themselves while solving mathematical problems, and the sixth one describes the results of those activities. Trained scorers are required to evaluate the activities of the subjects and inter-scorer agreement on rating is essential for obtaining an accurate measure of mathematical
creativity. Besides, teachers' ratings of pupils' creativity in mathematics were obtained and correlated with pupils' composite scores on mathematical creativity tests and the correlation was not higher than 0.30 (Prouse, 1965; 1967).

1.3-2 Limitations of Mathematical Creativity Tests: Tests developed to measure creativity in mathematics are by no means foolproof. Some of the drawbacks include the following:

- The sample used in the standardisation of the instruments is rather small.
- The sample often consisted of school students.
- Most tests do not provide adequate norms.
- Although some attempts have been made to establish the construct validity of the creativity tests through computing inter-correlations among the measures of fluency, flexibility and originality derived from the tests and through establishing concurrent validity by correlating test scores with scores on other creativity tests, the validity of creativity tests leaves much to be desired.
- The instruments often focus more on the intellectual than on creative abilities.
- The problem of reliability of mathematical creativity tests has not been settled satisfactorily. Of course, for some instruments test-retest reliability and split-half reliability estimates are available.
(the former range between 0.63 and 0.70, while the latter, between 0.42 and 0.82).

Lack of evidence to establish the fact that pupils identified as highly creative by these mathematical creativity tests do really make a mark as creative mathematicians in their adulthood. Thus, the predictive efficiency of these instruments has not been adequately established. Longitudinal studies involving children from different sexes, localities, socio-economic status, cultures and nationalities can indicate such predictive validity of these measures.

In summary, it may be said that all these creativity tests in mathematics are limited to research use and the number of commercially available standardised tests is meagre.

Despite the weaknesses of the mathematical creativity tests, they have been found useful for identification of creative potential in mathematics in a way different from that of intelligence, aptitude or achievement tests. Without these tests many potentially creative pupils in mathematics will remain unidentified and will have little chance for fruition of their potentiality. They have drawn the attention of educators to the need for encouraging divergent thinking besides convergent thinking abilities in the teaching-learning situations in mathematics classes.
1.3.3 Mathematical Creativity Tests versus General Creativity Tests: The belief that general creativity tests can yield scores which are also indicative of creativity in different areas of human endeavour including mathematics has slowed down the process of developing separate tests for the measurement of mathematical creativity. For example, Getzels and Jackson (1962) included items such as "Hidden Shapes" and "Make-up Problems" in their general battery of creativity tests to assess divergent thinking abilities in mathematical situations. These are used in combination with other open-ended type items of a general nature. But the tests of mathematical creativity designed to evaluate divergent production abilities, viz. fluency, flexibility and originality, have included items related to mathematical situations only. The distinction between mathematical creativity and other creativity tests has also been made on the basis of available evidence which shows that those who scored high on mathematical creativity tests failed to score as high on tests of general creativity (Chitrivan, 1982).

Further, the low correlations between scores on mathematical creativity tests and tests of general creativity have been cited as evidence for the independence of the two types of tests. (Balka, 1975, Zosa, 1978). The independence of these two categories of tests has also been established to some extent by certain correlational
studies. For instance, Lanier (1967) and McGannon (1971) have reported low correlations (r's ranged from 0.20 to 0.40) between the scores on tests of general creativity and intelligence. But Spraker (1961), Banghart and Spraker (1963), Prouse (1965), Evans (1965), Balka (1975) and Salandanan (1976) have reported positive and moderately high correlations (r's ranged from 0.48 to 0.59) between mathematical creativity and intelligence. Thus intelligence is more closely related to performance on mathematical creativity tests than general creativity tests.

1.3-4 Mathematical Creativity Tests versus Intelligence Tests: It is, of course, true that tests of creativity in mathematics tend to correlate to some extent with the tests of intelligence. This, however, does not imply that the latter category of tests can measure creative ability in mathematics quite successfully. The reasons for the limited scope of traditional intelligence tests in assessing creative abilities are not far to seek. Most of the conventional tests of intelligence assess basic mathematical skills and abilities such as numeration, computation, memory, reasoning and other cognitive abilities through items each of which demands a single, absolutely correct and conventional response. These tests fail to tap divergent production and transformation abilities which are closely associated with creativity in mathematics.
It is often asserted that above-average intelligence is a necessary but not a sufficient condition for a high degree of performance on mathematical creativity tests (Evans, 1965). Evans' conclusion is related to Anderson's (1960) 'Ability Gradient Theory', which, if applied to the subject of mathematics, holds that there is a threshold level of intelligence beyond which creative abilities begin to affect performance in mathematics (Aiken, 1973). The IQ threshold hypothesis has also been supported by some researchers like McKinnon (1962), Torrance (1962), Vernon (1964), Yamamoto (1964a), Raina (1986). The hypothetical threshold point may lie between 120 and 140 IQ (Cropley, 1967b). But Spraker (1961), Banghart and Spraker (1963), Acharyulu (1977) found from their studies, designed to determine the relationship between intelligence, creativity and mathematics achievement, no evidence for Anderson's 'Ability Gradient Theory'. Nevertheless, the traditional intelligence tests do not identify children who are highly creative in mathematics. Mathematical creativity tests need to be used for this purpose.

1.3-5 Mathematical Creativity Tests versus Mathematical Aptitude Tests: Creativity in mathematics is, no doubt, influenced by mathematical aptitude to a large extent, but mathematical aptitude is not the sole determinant of creativity. Non-aptitude traits and environmental factors, too, contribute their share towards creativity in mathematics. This implies that an estimate of mathematical aptitude may
not truly reflect a pupil's creative ability in mathematics. In other words, mathematical aptitude alone cannot assist in the identification of pupils with high mathematical creativity. This is supported by Jensen (1973) and Zosa (1978) who reported low correlation between these two categories of tests. Tuli (1981, 1985), however, has reported statistically significant relationship between mathematical aptitude and mathematical creativity.

1.4 Creativity and Study Habits in Mathematics:

'Study Habits in Mathematics' usually refer to the methods and techniques normally used by pupils in learning mathematics. A pupil's study habits largely depend upon whether he/she aims at "comprehension learning" or "operation learning" (Pask, 1976), "deep level processing" or "surface level processing" (Marton and Saljo, 1976), or academic achievement (Watkins and Hattie, 1980; Entwistle et al., 1979; Biggs, 1978, 1979). Laurillard (1979) wrote: "students choose their study methods according to their perception of the task itself and the style of teaching and their own orientation to the task". As a consequence, wide variations in the habits of studying mathematics are noticed among pupils.

Osborn (1953) hypothesised that certain habits such as travelling, playing games, solving puzzles, pursuing hobbies, reading and writing develop creative ability.
Thorndike (1931) has also emphasised the role of habits and past experience in creative thinking. To him, all "novel", "insightful" or "creative" thought is the result of association rather than reasoning. Barron's (1955) observation, "there is good reason for believing, however, that originality is almost habitual with persons who produce a really singular insight", seems to support Thorndike's conception of creative thinking. This view implies that pupils should have prolonged practice in desirable habits of creative thinking. Good study habits in mathematics may, therefore, be expected to promote creative production in this field. If pupils develop the habit of analysing a given mathematical situation in several ways, searching for as many alternative hypotheses as possible for its solution, trying out those hypotheses one after the other until the correct solution is reached, and of further verification of the solution, they are quite likely to master the complex skills of creative thinking in mathematics. This is, however, an assumption worth examining.

1.5 Pupils' Perception of Teachers' Impressions about their Performance in Mathematics and Creativity in Mathematics:

It has been hypothesised that a climate of psychological safety and freedom is conducive to creativity (Rogers, 1959). Parents, teachers and other
significant adults in the immediate environment of the child are responsible for creating this type of climate. This can be possible provided they believe in his/her potentialities, accept him/her in spite of his/her follies and weaknesses, and ensure complete freedom to express his/her ideas and experiences in whatever form he/she likes without the threat of external evaluation.

In the school this climate or learning environment should have several components - viz. human, physical and emotional (Laycock, 1970). The human environment consists of interaction between the teacher and the pupil and among pupils themselves in the classroom, laboratory, library and playground. The physical environment is made up of a wide variety of materials to be manipulated by the pupils for the discovery of general concepts, principles or theories through imaginative inquiry. The emotional environment, the most important of the three, depends solely on the personality of the teacher. He should play the role of a 'sponsor' or 'patron' who encourages and supports pupils to express and test their ideas even if they seem 'silly' or 'crazy' and provide a refuge until they try out and modify, if necessary, those ideas (Torrance, 1962).

When a pupil feels that he/she has a patron in the mathematics teacher who will appreciate his/her failures as well as achievements, and come to his/her rescue in the face of criticism from others, he/she may be willing
to take risk and try out novel mathematical ideas and combinations. Thus, favourable pupils' perception of their teachers' impression about their performance in mathematics seems to be a significant factor in fostering mathematical creativity. Although the relationships among pupils' perception of their teachers' feeling towards them and their self-concept, school achievement and classroom behaviour has been studied (Davidsen and Lang, 1962), the influence of pupils' perception of their teachers' impressions about their performance in mathematics on their mathematical creativity has not yet been explored.

1.6 Need for the Study:

Explosion of knowledge, especially in the field of science and technology, has brought about unprecedented revolution in agriculture and industry on the one hand, and rapid growth in the size of the world population on the other. Consequently, all the efforts of a nation, no matter however intensive and sincere, directed towards providing basic amenities of life to its citizens falls far short of their growing needs and demands. Problems of the nation gradually increases in dimension and complexity, and at times find expression through social unrest and change in the system of government. The problems of the developing nations, that have thrown off foreign yoke in the recent past, and strive to attain the economic standard
of the developed countries, grow more acute day by day, and pose a serious threat to their independence. To provide the basic needs of life for the huge masses of people living under abject poverty and untold misery, these countries are in great need of both material and human resources. They have, therefore, joined the frantic search for and promotion of creative potentials, especially in science and technology.

In our own country the Central Government is also committed to this important task and it has been implementing two schemes - The National Talent Search (NTS) Scheme and The Rural Talent Search (RTS) Scheme - with the help of the National Council of Educational Research and Training (NCERT) and the State Departments of Education respectively. Every year the NCERT conducts an examination at the national level at the end of classes X and XII for identification of talents under the NTS Scheme. The Rural Talent Search Scheme, being operated by the Ministry of Education, Government of India in collaboration with the State Departments of Education, is for identifying talented children in rural areas. Tests developed by the respective State Departments of Education are given to students studying in Class VII for this purpose. Pupils identified as the most talented are awarded stipends to continue further studies. In addition to these massive programmes of talent search and talent promotion, the Central Government also provides funds to
institutions and individuals through the University Grants Commission to encourage research in the field of creativity. Unfortunately, research in the area of creativity is still in its infancy in India, and research in mathematical creativity is yet to get off the cradle. Further, the relationships among mathematical creativity, study habits in mathematics, pupils' perception of their teachers' impressions about their performance in mathematics, need to be explored. The present study is taken up for this purpose.

1.7 **Definition of the Terms Used:**

Creativity in Mathematics (or Mathematical Creativity) is operationally defined as the ability to produce a large number of varied but mathematically tenable responses to mathematical problem situations presented in the test entitled 'Mathematical Creativity Search Battery' developed for the purpose. The test is scored for three creative thinking abilities, viz: Fluency, Flexibility and Originality. These abilities are operationally defined as follows:

**Fluency** is defined as the ability to produce as many ideas/solutions as possible to given mathematical tasks/situations.

**Flexibility** is defined as the ability to produce as many different classes or categories of ideas/solutions as possible to given mathematical tasks/situations.
Originality is defined as the ability to produce uncommon, unique or novel but tenable responses to given mathematical tasks/situations. It is derived in terms of the statistical infrequency of the responses.

Study Habits in Mathematics (SHM) refer to all the typical practices followed by pupils in the study of mathematics.

Pupils' Perception of Teachers' Impressions about their Performance in Mathematics (PPTIPM) is used to refer to the perceptions of pupils regarding the impressions the mathematics teachers have about their performance in mathematics.

Achievement in Mathematics refers to the average marks obtained by the pupils in the half-yearly and annual School Examinations in mathematics.