CHAPTER II
REVIEW OF RELATED RESEARCH

The focus of the present study was on the relationship of Pupils' Mathematical Creativity to their Mathematics Study Habits and Perception of Teachers' Impressions about their Performance in Mathematics. The effects of such factors as sex, locality, caste, birth order, home study time for mathematics, rank in mathematics tests and pupils' self-assessment of mathematics performance on their creative thinking abilities in mathematics also formed a part of this study. The need for such an attempt arose from the paucity of available research on the relationship among Study Habits in Mathematics, Pupils' Perception of Teachers' Impressions about their Performance in Mathematics and Mathematical Creativity.

The available research related to the present study was presented under the following heads:

- Studies on the relationship between Teaching-Learning Strategies and Mathematical Creativity.
- Studies on Mathematical Creativity as related to certain Personality Traits.
- Studies on the relationship of Mathematical Creativity to Achievement in Mathematics.
- Studies dealing with Sex differences in Mathematical Creativity.
- Studies on Rural-Urban differences in Mathematical Creativity.
2.1 Studies on the relationship between Teaching-Learning Strategies and Mathematical Creativity:

The relative effectiveness of different teaching-learning techniques in promoting creative problem-solving abilities in mathematics was assessed by several investigators. Research in this area was broadly classified as studies which estimated the effects of instructional materials/programmes, and studies which explored the influence of novel methods of instruction on creative problem-solving in mathematics. These studies were briefly described below.

2.1-1 Studies on the effects of Instructional Materials/Programmes on Creative Problem-Solving in Mathematics: The effects of different types of instructional materials/programmes on pupils' creative problem-solving abilities were studied by some investigators. The merits of these instructional programmes in promoting creative problem-solving abilities in mathematics were reported by the following studies.

Brian (1967) assessed the effects of pupils' knowledge in the processes of mathematics on their mathematical problem-solving behaviour. He defined the processes of mathematics as the processes of (i) constructing mathematical models, (ii) conjecturing, (iii) distinguishing between true and false conjectures, and (iv) using known or given axioms and theorems or algorithms on problems where
applicable. Each process was illustrated by exemplary material, and a behavioural flow chart related to mathematical problem-solving activity was developed. About two weeks' training in those process activities (behaviour) was given to a group of seventeen students admitted into an upper division mathematical problem-solving course of San Jose State College, San Jose, California. The subjects were pre- and post-tested by an initial test and a final test respectively. Those two tests were developed by the investigator to determine the effectiveness of the short-course training in improving subjects' ability to use mathematics processes in solving problems. A standard spatial relations ability test was also used by the investigator to determine the extent to which the scores obtained on this test could predict subjects' ability for using processes conducive to mathematical problem-solving. A comparison of the scores on the initial and final tests revealed a significant improvement in their ability to distinguish between true and false conjectures. Comparing the scores on the spatial relations ability test with those on each part of the initial and final tests no significant relationship could be found between spatial relations ability and problem-solving activities.

Gage (1984) compared the merits of forming and solving original mathematics word problems with those of solving ready-made word problems in mastering processes and
strategies used in mathematical problem-solving. His sample consisted of twenty male and twenty female students drawn from a vocationally oriented urban community college. The subjects were interviewed individually. One or two practice problems, five Problem-Forming Situations (PFSs) developed by the investigator were given to the subjects alternately with five Ready-Made Problems (RMPs). The subjects were asked to create a challenging word problem for each PFS. Each subject's performance on forming and solving problems were audio-taped, and his/her score depended on the range of processes and strategies used in completing each type of assignment. For each type of task, means of the entire group, ten most able and ten least able RMPs-solvers were computed. It was observed that the subjects used a wider range of processes and strategies, including those previously undiscovered, and applied checking processes more frequently during PFSs than for RMPs. Further, random selection of solutions on an irrelevant basis during the former situations was almost half of that observed during the latter situations. The study reported that mathematical thinking increased during PFSs.

The effects of a "Divergent Thinking Programme in Mathematics (DTPM)" on verbal creativity of school children were also studied by Vora (1985). The sample for the study consisted of 271 children studying in classes VII
and VIII in a Gujarati medium school complex in Ahmedabad, India. Children in each class were divided into three groups - one control and two experimental groups. In all, two control groups (N=90) and four experimental groups (N=181) were involved in the experiment. The investigator prepared a DITPM instrument consisting of 6 multi-response type items (2 items each for arithmetic, algebra and geometry), 3 'hidden shapes' items from geometry and 3 'make up problems' items from arithmetic data presented in a story form. The four experimental groups received 2 DITPM items per week for six weeks, while the two control groups received no such treatment. Further, one experimental group from each standard was given training to solve the DITPM items assigned to them, while the other experimental group responded to the DITPM items without receiving any training. The whole sample was pre- and post-tested by Passi's Tests of Creativity (PTC). The differences in the adjusted Means between the control and experimental groups (combined) for each standard was found significant at the 0.05 level, and the difference favoured the experimental groups (combined). Thus, the DITPM was found to be effective in improving the creative abilities of the subjects.

Although the studies mentioned above showed some evidence regarding the positive impact of instructional materials/programmes on fostering Creativity, there have been studies which contradicted such findings. Some
of these studies are given below.

Treffinger (1969) studied the effect of programmed instruction materials, intended to foster productive thinking, on the verbal creativity and mathematical problem-solving of school children. The sample consisted of 370 pupils of grades IV to VII drawn from six public schools in Central New York State. Two classes at each grade level were randomly assigned to experimental group, and the others were included in the control group. Covington et al (1966) "Productive Thinking Programme" was used with the experimental group. A General Problem Solving Test, and two forms of an Arithmetic Problem Solving Test were used as the criterion measures for determining the extent of transfer of learning from programmed instruction to problem-solving. The Make-Up Problems Test (Getzels and Jackson, 1962) and a Childhood Attitude Inventory for Problem Solving were used to measure the extent of non-specific transfer of learning to subject-matter problem-solving. Scores on Verbal Creativity, General Problem Solving, Arithmetic Problem Solving (both forms), and Make-Up Problems Test indicated that programmed instruction had no significant effect on both verbal creativity and mathematical problem-solving ability. The experimental groups at each grade level, however, showed significantly better performance than the controls on the Childhood Attitude Inventory for Problem Solving.
Meyer (1970) designed an instructional programme to encourage the mathematical creativity of the first graders. On the basis of two pilot studies, the investigator identified certain activities which satisfy a set of conditions supposed to promote mathematical creativity, and selected activities suitable to first graders. Some of these activities were used for developing an instructional programme aimed at fostering creativity in mathematics, while the others were incorporated in the creativity test developed by him. The pupils were made to participate in the specially developed instructional programme which took the form of fifteen daily lessons. Each lesson was of twenty minutes duration. After this they were given the creativity test. Their problem-solving behaviours were video-taped and evaluated by trained scorers according to the six pre-validated criteria used in designing the creativity test. In addition, Torrance Tests of Creative Thinking, Figural Forms A and B, were used as a measure of the effects of the instructional programme on general creativity of the subjects. The results revealed that the specially designed creative instructional programme did not have any significant effect on both general and mathematical creativity test performance.

Roth (1983) studied the relative efficacy of the word-problems formulated by him over the word-problems given in mathematics texts in improving problem-solving abilities of sixth-grade pupils. IOWA Test of Basic Skills, Dutton Arithmetic Attitude Scale, and the Arnold Problem-Solving
Test were used in the study. The experimental group was given mathematical word-problems developed by him, while the control group was asked to solve text-book word problems. Inspite of the experimental group spending an additional one and one-half class periods per week compared to the control group, no significant differences were found between the two groups on computation skills and problem-solving abilities.

Thus, no conclusive evidence could be found regarding the merits of instructional materials/programmes in developing mathematical creativity.

2.1-2 Studies on the Influence of Novel Methods of Instruction on Creative Problem-Solving in Mathematics: The search for the most effective method of study/instruction that would develop and promote creative problem-solving abilities in mathematics has resulted in experimenting with different novel instructional techniques. Some investigators have tried out the effectiveness of group-study/instruction strategies on the one hand and compare the relative merits of group- and individual-study/instruction techniques on the other.

Coulson (1965), for example, used a sample of 615 Southern California Junior College students to test the effect of "openness to experience" on objective problem-solving in small groups. The subjects included in the sample were randomly assigned to four experimental conditions,
namely, 'a democratic leader group condition', 'a leaderless control group condition', 'an openness-to-experience leader group condition' and 'an openness-to-experience leaderless group condition'. Subjects assigned to all the experimental conditions were required to discuss the process of solving Maier's "horse trading problem". The leaders and members respectively of the latter two experimental conditions were instructed to be "open" to the suggestions of other members of their own group during the discussion directed towards the solution of the problem. Irrespective of the experimental condition to which they belonged, all the subjects were asked to solve the problem individually before and after the group discussion on the process of solution. The number of subjects who could improve their problem-solving performance after the group discussion under each experimental condition provided the measure of the dependent variable. The results revealed that improvement in problem-solving performance of the members of the 'democratic leader groups' after the discussion was significantly poorer than that of the members in the 'leaderless control groups'. Members of the 'openness-to-experience leaderless groups' showed significantly greater improvement in their problem solving performance following the group discussion than those of any other group except those with "open" leaders. However, "openness-to-experience" failed to improve the problem-solving performance of the "open" leaders after the group discussion.
Hart (1935) also reported the merit of group-study method in solving mathematical problems in his clinical study. The sample for the study consisted of twelve seventh grade students of average ability from a middle class urban elementary school. The sample was divided into four groups of equal size. All the groups had three sessions. In the first session, the individuals were given a Problem Solving Sort Task and a Problem Solving Attitude Questionnaire. In the second session, the subjects were given an applied mathematical problem and their problem solving activities were video-taped. In the third session, a follow-up discussion was arranged with each group and this was audio-taped. Percentages of success in the Problem Solving Sort Task and the Problem Solving Attitude Questionnaire were computed. The transcriptions of video-taped and audio-taped sessions were also analysed. The results revealed that the presence of other members in the group facilitated the problem-solving process in the sense that the members could frequently supply and discuss relevant background information for solving the problem. The interaction of group-members served as a sort of monitoring mechanism in the problem-solving process. The group allowed time to its members to think of different modes of solving the problem. On the basis of these findings Hart concluded, "The small group is a useful tool for studying problem-solving and may also prove to be a useful pedagogical format of problem-solving instruction".
Studies of Coulson and Hart, thus, pointed to the merits of small group-study/instruction techniques in improving mathematical problem-solving. But the following studies could not find the superiority of small group-study/instruction techniques over the individual-study/instruction in promoting creative problem-solving abilities.

Spraker (1961) explored the relative efficiency of group- and individual-study methods in developing creative abilities for mathematical problem-solving. The sample for the study was drawn from eight seventh grade classes. A standardised mental abilities test and an arithmetic achievement test were administered to all subjects prior to the beginning of the instructional programme. Those scoring high on IQ, arithmetic achievement and teacher's judgement were assigned to two classes. These classes were designated as "High" classes. Similarly, those who were found to be average were designated as "average" classes, and there were four such classes. The others who were low on these three were grouped into two "low" classes. Group- and individual-study treatments were randomly assigned to classes at each of the three levels, and subjects assigned to group-study treatment were also randomly assigned to a number of small groups consisting of six to eight members each. All the subjects were taught the same mathematics content and the teachers encouraged them to solve mathematical problems in different possible ways. It was observed that the subjects assigned to two
different treatments did not differ significantly in their performance on the mathematical creativity test developed by the investigator, when the scores were adjusted for IQ and arithmetic achievement. However, the creativity scores of the subjects in the "high" classes were significantly higher than those of the subjects in the "average" and "low" classes; and the subjects included in the "average" classes were favoured with significantly higher creativity scores than their counterparts in the "low" classes.

Banghart and Spraker (1963) also came to the same conclusion as was reported by Spraker (1961) from a similar experiment. The objectives of their experiment were (i) to estimate the effect of working in a group on creative problem-solving in mathematics and (ii) to determine the relative superiority of group versus individual work in promoting creativity in mathematical problem-solving. The sample consisted of 180 subjects drawn from intact seventh grade classes in an urban junior high school. A standardised arithmetic achievement test, a mental maturity test and creativity test in mathematics problem-solving (Part I & II) developed by the investigators were used in this study. Two "high", four "average" and two "low" classes were formed out of the sample on the basis of the performance of the subjects on the standardised arithmetic achievement test and the mental maturity test. These classes were assigned to two experimental groups. Each group had one "high", two "average" and one "low" classes. Both the groups received
instruction on the same two units from the mathematics text, but the method of solving problems was not explained to any group. Both the groups were encouraged to solve problems in different ways. One experimental group (N=87) was required to solve problems in cooperation with others in the group. The other group (N=93) was asked to solve the same problem individually without exchanging ideas or taking help of other members of the group. Part I of the creativity test was administered to both the groups at the end of the instruction on the first unit of the mathematics text and the second part of the creativity test was given after the completion of the second unit. The study did not find any significant differences between group and individual problem solvers in terms of creativity. However, significant differences in creative problem solving abilities attributable to intelligence were found.

Gilbert-Machillan (1984), too, reported no significant differences in the problem solving performance of students working in small groups and those working individually. His sample consisted of students drawn from four fifth-grade classes. Subjects of two classes were divided into four-member groups and were given three different types of mathematics word-problems, viz. computational, text-book and real world problems, with the instruction to solve them on cooperative basis. The same problems were also assigned to the other two classes. These classes, as a whole, were taught the heuristic strategies in solving problems and then
they were required to work out the problems individually. The subjects were exposed to nine problem-solving sessions. They were pre- and post-tested on each problem category, on a standardised mathematics concept test, and on an attitude scale. The results revealed no significant differences in the performance of students working in cooperative small groups and those working individually. The subjects taught as a whole class tend to show significantly more liking for word problems than those who worked in small groups.

Thus, no conclusive evidence could be found regarding the relative effectiveness of group versus individual study/instruction on mathematical creativity.

A number of studies also explored the merits of other instructional methods in improving pupils' mathematical problem-solving abilities. Some of those studies are given below.

Faulk (1961) studied the influence of a comprehensive method of instruction on problem-solving achievement in arithmetic. His method of instruction included several phases, such as pupil participation in vocabulary exercises, talking through the problem situations, diagramming and illustrating problems, estimating answers and writing solutions. Two schools with similar class-rooms that introduced the same series of text-books and volunteered to participate in the experiment were selected from each of
11 Parishes in the State of Louisiana. Within each Parish, students from similar intact class-rooms were paired on the basis of sex, age, IQ and arithmetic achievement. In all, 74 pairs of sixth grade students representing the 11 parishes were randomly assigned to experimental and control groups. Twentytwo teachers were involved in the experiment and they were paired on the basis of their academic qualification, length of teaching experience, and professional competency. The instructional techniques recommended in the teacher's guide of the Making Sure of Arithmetic Services were used in teaching arithmetic problem-solving in the control group. The experimental group was taught by the method devised by the investigator. The experiment continued for 18 weeks and was supervised by the local educational supervisors of the respective Parishes as well as by the State Elementary Supervisor. The California Test of Mental Maturity and the California Arithmetic Reasoning Test were administered to both the groups in September, 1959 and the latter test was again administered in January, 1960. On the basis of their grade placement, the subjects within the 74 pairs were divided into the upper, middle and lower thirds, and the differences in the mean gains from pre-test to post-test Arithmetic Reasoning Scores were computed and analysed for these three smaller groups. These results indicated that the experimental procedure was slightly superior to control group procedure, although both the procedures were effective in improving problem-solving achievement. It was also found that only the mean gains
of the total experimental group were statistically significant, whereas the mean gains of the experimental groups were slightly higher than those of the corresponding control groups.

Darch's (1983) study was, however, primarily concerned with estimating the relative effectiveness of a Direct Instruction method and a Traditional method in teaching mathematics word story problems. The study was confined to seventy-two fourth grade pupils who were randomly assigned to one of four experimental groups, designated as (i) Direct Instruction with fixed amount of practice, (ii) Traditional Instruction with fixed amount of practice, (iii) Direct Instruction with extended practice, and (iv) Traditional Instruction with extended practice. Subjects in each group were taught in small groups of two to four members for 35 minutes daily. 120 multiplication and division story problems were assigned to the two groups with fixed amount of practice; while up to eight additional lessons were given to the two extended practice groups. The two groups assigned to Direct Instruction method were instructed in modelling step-by-step strategies for solving different types of problems. In the two other groups receiving Traditional Instruction treatment, the modelling of step-by-step strategies was not explained, but the subjects were taught the process of solving problems. Immediately after the treatments, the subjects were given a test consisting of 26 word problems, and a parallel form maintenance test
followed the first test 10 days later. From the post-test results it was noticed that the performance of both Direct Instruction groups was significantly higher than that of the Traditional Instruction groups. But provision of extended practice produced no effect, although it improved the performance on maintenance test to some extent only for the Direct Instruction groups.

Unlike the previous studies, Hooda and Jariail (1983) sought to determine the effects of teaching mathematics through the strategy of mastery learning on non-verbal creativity. Their experiment involved 55 students admitted into two sections of class VI in a middle school located in Indore City, Madhya Pradesh (India). The two sections were comparable on their mean creativity scores in many of the five dimensions - fluency, flexibility, originality, elaboration, and total creativity scores - provided by the Torrance Tests of Creative Thinking, Figural Form A. Both sections were taught the same subject-matter content in mathematics by the same teacher using the traditional method. But one section which received the experimental treatment was required to acquire 80% mastery over each unit taught in the class, whereas this criteria of learning was not prescribed for the other section forming the control group. A school period of 30 minutes' duration was utilised everyday for a period of six months to complete the course content. Both sections were then post-tested by the Torrance Tests of Creative Thinking, Figural Form B, and
the differences in the mean gains from pre- to post-test creativity measures between the two sections were computed. The results indicated significant differences (at the 0.001 level) in favour of the experimental group in all the five dimensions of non-verbal creativity measures, and led the investigators to conclude that mastery learning strategy was more effective than traditional method of teaching mathematics in developing non-verbal creativity in pupils.

Payne (1984) simultaneously tried three instructional techniques designed to develop the power of understanding problem-structure, and discovery of the solution. Seventy-two students enrolled for the General Education Mathematics course at Florida College during the Spring Semester, 1983 were the subjects of his study. The subjects were randomly assigned to three groups consisting of 27, 25 and 20 members respectively. All the groups were tested on Nelson-Denny Reading Test, SAT Verbal and Mathematics Test and SRA Intelligence Test; and no significant differences in the variables measured were found between the groups. The three treatments, viz. Flow Charting (F) Method, Heuristic (H) Method and Structured Questioning (S) Method of instruction in mathematical problem-solving, were randomly assigned to the three groups. All the groups were taught by the investigator. But the Flow Charting method, which was similar to programming problems for a computer, was used
for the F-group consisting of 27 subjects. The 25 member H-group was taught through Polya's Heuristic Method, and the S-group of 20 subjects received instruction through Structured Questioning technique designed by Philips and Soriano. Pre-tests, post-tests and retention tests designed by the researcher were administered to all the groups to measure subjects' ability to solve typical and novel verbal problems and the ability to retain the technique of problem-solving taught to them. Comparison of the pre- and post-tests means and the post- and retention-tests means for all the groups revealed that all the three instructional techniques were effective in improving significantly pupils' problem-solving ability on typical and novel verbal problems and in retention of the improvement.

Luckinich's (1984) experiment estimated the merits of teaching diagrammatic modelling and sentence writing in improving verbal and numerical problem-solving abilities of 48 Second Grade Pupils enrolled in a public elementary school located in a low socio-economic area. An experimental and a control group were formed out of the sample by random assignment of subjects to the two groups. Both groups were administered a pre-test, followed by 26 lessons of half-hour duration each on verbal problem-solving. The experimental group was instructed in diagrammatic modelling and in writing number sentences which was supposed to help problem-solving. The control
group received no such instruction, but the same type of problem as given to the experimental group. Finally both groups were post-tested. The mean gain of the experimental group on the post-test over the pre-test measures was significant at the 0.01 level. The experimental treatment was effective in improving problem-solving ability of the subjects.

Walter (1985) investigated the effectiveness of a pictorial representation method of instruction in improving pupils' mathematical word problem-solving ability. The study was confined to 233 seventh grade students from a suburban middle school in New Brunswick, in the State of New Jersey. The subjects were divided into two heterogeneous groups - the experimental and the control groups. The experimental subjects were given instruction in constructing pictorial representation of problem statement. It was expected that this treatment would enable those, who had the knowledge of fundamental mathematical structures and ability to restructure information, to solve problems successfully. The control group received no such treatment. Both groups were given identical pre- and post-tests. The subjects were required to complete a combinatorial logic task, a cognitive restructuring task, and a task intended to measure the understanding of commutative, identity and inverse properties. The grade level score on the problem-solving section of the IOWA Test of Basic Skills represented each
subject's achievement in problem-solving. No significant improvement in problem-solving achievement ability was observed in the experimental subjects. While cognitive restructuring and understanding of fundamental mathematical structures had significant contribution to successful problem-solving, the contribution of combinatorial logic was not significant.

Thus, the merits of novel methods of teaching mathematics in improving pupils' problem-solving ability were reported by most of the studies described above.

In some experiments the effects of different combinations of instructional methods, instructional method and material, or of method, material and instructors on creative problem-solving were explored.

Buckeye (1968), for example, made an attempt to determine the extent to which a 'creative classroom environment' increased the creative ability of prospective elementary mathematics teachers. The study was limited to 145 prospective elementary mathematics teachers admitted into a content mathematics course at the Indiana University. From the total sample, 95 subjects were randomly assigned to experimental group and the remaining 50 formed the control group. Both groups received instruction in the same mathematics course content. The control group was taught by lecture method, whereas lecture-cum-intuitive and question-answer methods were used for the experimental
group. Less than 25% of the class periods was devoted to lectures, and more emphasis was given to intuitive and question-answer technique in the experimental group. The experimental subjects were assigned challenging problems to develop their creative thinking, encouraged to ask questions relating to those problems, suggest novel methods of solution and evaluate their own ideas. They were shown that their unusual ideas were not worthless. They were given opportunity to teach and explain problems in the class. In short, the experimentals were exposed to a creative learning environment along with lectures. Before and after the instruction, both groups were administered the AC Test of Creative Ability. Comparison of the pre- and post-test measures of creativity of both the groups showed a significant increase in the creative ability of the experimentals and a significant decrease in the creative ability of the controls.

Baur (1971) studied the improvement in Mathematical Creative ability as a function of different treatment combinations of classroom environment, creative problems, and type of instructor. The study was limited to eight intact classroom groups consisting of 161 students enrolled in a course entitled, "Mathematics for Elementary Teachers I" during the Fall and Spring Semesters at the Indiana University in 1969-70. The combinations of classroom environment and creative problems were randomly assigned to different classes, and the instructors, each of whom
was either a teacher-educator or a pre-mathematician, were assigned to different treatment combinations at random. All the instructors taught the same mathematics content prescribed in the course syllabus, gave regular assignments, tests etc. on their own. The sections which received creative problems had five minutes discussion daily on the problems assigned to them the previous day. These subjects were encouraged but not compelled to solve those problems. Researcher designed Test of Creative Ability in Mathematics, Form A and an achievement test were used in pre-testing while a Test of Creative Ability in Mathematics, Form B and an achievement test served as post-test measures. The SAT mathematics and verbal scores for each subjects were used as variables in a multiple linear regression equation with the pre-test achievement as the criterion variable to develop a predictor of achievement. Significant differences in mean gains from pre- and post-test measures of Creative Ability in mathematics were found between (i) the group exposed to creative class-room environment and the group not so exposed, (ii) the group that received creative problems and that did not receive such problems, and (iii) the group taught by a mathematics-educator and that by a pre-mathematician. A creative class-room, a creative problem and a mathematics-educator were found to increase the Creative Ability in mathematics.

Mainville (1972), however, explored the relative effectiveness of two combinations of instructional methods
and materials in developing creative thinking ability. The two combinations were - lecture-cum-textbook technique, and lecture-cum-Mathematics Activity Materials technique. The Mathematics Activity Materials were given in thirty three 'Activity Sheets' developed by the investigator and were supplemented by concrete materials. Students enrolled for the Fall semester, 1971 in Elements of Mathematics course at the Portland Campus of the University of Maine were the subjects of the study. One section consisting of 30 students formed the experimental group, and another section of 24 students was designated as control group. Both groups were taught the same content in Mathematics by the investigator and were also given the same home-work, course-guide and quizzes. The same informal instructional technique was followed; open-ended questions were used and emphasis on eliciting subjects' response was given in teaching both the groups. But the control group was taught by lecture-cum-textbook method, whereas the experimental group received instruction with the use of Mathematics Activity Materials along with lectures. Less than one-half class period on the average was devoted to lectures in the latter group, and the remaining time was utilised for individual and small group activities. Activity sheets prepared by the investigator and concrete materials required to supplement them were used by the subjects. Pre- and Post-test measures of Mathematical creativity for both groups were obtained by a Mathematics Creativity Test, Forms A and B, developed by the investigator.
The mean and the difference of pre- and post-test measures of Mathematical Creativity were computed for each group separately. There was no significant differences in the mean Creativity measures between the two groups. The results indicated that mathematical activity materials could not increase the mathematical creativity of the experimental group. However, both groups had significant gain in post-test mathematical creativity measures over their pre-test scores. This finding proved that an informal instructional technique in teaching mathematics course content had increased the mathematical creativity of both groups.

Roberts (1984) studied the efficacy of the traditional lecture-cum-demonstration method of instruction over a combination of traditional method and creative problem-solving technique on improving pupils' conceptual and creative problem-solving ability. Two classes from the Summer Semester and two classes from the Fall Semester were involved in the study. One Summer Semester class and one Fall Semester class were randomly selected to constitute the experimental group, and the other two classes formed the control group. The experimental group was taught College Algebra by the traditional-cum-creative problem-solving technique. The same course content was taught to the control group by the lecture-cum-demonstration method. Both the groups were pre- and post-tested using
an algebra test prepared by Amsco School Publications, and Verbal Reasoning and Numerical Ability of the Differential Aptitude Tests. Data on both classes forming each group were combined for analysis. The post-test means of verbal reasoning, numerical ability or achievement in algebra revealed no significant differences between the two groups.

In view of the conflicting findings reported by the studies included in this category, no definite conclusion regarding the efficacy of novel methods of instruction in fostering creative ability in mathematical problem-solving could be drawn.

2.2 Relationship between Non-intellectual Personality Traits and Creativity in Mathematics

A few studies were addressed to the task of identifying non-intellectual personality traits that facilitate or are related to creative ability in mathematics. All such studies might be classified under the following categories:

(i) Studies which investigated the relationship between attitude towards mathematics and creative ability in mathematics.

(ii) Studies that determined the relationship of other personality qualities to mathematical creative ability.
Studies which investigated the Relationship between Attitude Towards Mathematics and Creative Ability in Mathematics: The relationship between Creativity in Mathematics and Attitude Towards Mathematics was explored by the following studies.

Evans' (1965) study reported significant positive correlation between the two variables. His study was designed to measure the ability of late elementary and junior high school students to respond to creative mathematical situations. He developed and administered 16 tests to students enrolled in grades V to VIII at the University School, University of Michigan, for the purpose. A mathematical situation was presented in each test and the subjects were asked to respond in as many different ways as they could. Subjects' Mathematical Creativity measures were correlated with their measures of Mental Ability, General Creativity, Achievement and Attitude, and all correlation coefficients were found to be positive and statistically significant.

Buckeye (1968) also studied the effects of a creative class-room environment on the creative ability of prospective elementary mathematics teachers (N=145). One of the objectives of the study was to estimate the degree of relationship between creative ability, attitude, achievement and SAT measures. The AC Test of Creative Ability provided the measures of creative ability of the
subjects. Measures of creative ability were not found to be related to attitude towards mathematics.

Unlike the two previous studies, Keese (1972) compared the attitude of high and low creative students towards mathematics. Two intact eighth grade classes each consisting of 31 pupils were involved in the study. The whole sample was administered the Torrance Tests of Creative Thinking, Verbal Form A. On the basis of the mean total creativity scores, the subjects in each class were divided into high and low creative groups. One teacher taught both the classes the same unit on 'sequences and series' written by the investigator. He used discovery method of teaching in one class and expository method of teaching in the other. All the four groups thus formed were comparable in mathematical achievement as measured by the Metropolitan Achievement Test. An achievement test on the unit taught was prepared by the investigator and used at the end of the experiment. A scale to measure attitude towards mathematics was also given to the sample at the beginning and end of the experiment. This study reported no significant difference in the attitude towards mathematics between the high and low creative groups.

Tuli (1981) designed his study to explore the relationship of mathematical creativity to aptitude for achievement in, and attitude towards mathematics. The study was limited to a group of ninth grade high/higher
secondary school students selected by the technique of multi-stage randomization of cluster at district, block, school levels from the State of Punjab (India). CAMT (developed by Balka), NA, VR, AR, and MAS were the instruments used in the study. Subjects' marks in the Punjab School Board Examination were taken as measures of achievement in mathematics. The correlation coefficient between measures of Mathematical Creativity and Attitude towards Mathematics was not significant. He observed that either the two variables were independent, or attitude towards mathematics was not fully developed at this stage.

Tuli (1985) again investigated the relationship of mathematical creativity to attitude towards mathematics using a sample of only 439 girls drawn from class IX of high/higher secondary schools in the Punjab. He used CAMT, NA, VR, AR and MAS to obtain measures of mathematical creativity, numerical ability, verbal reasoning, abstract reasoning and attitude towards mathematics. No significant relationship between creative ability in mathematics and attitude towards mathematics was found in this study.

Thus, all but Evans (1965) reported that attitude towards mathematics was not significantly related to creativity in mathematics. The studies in this area are few and as such no valid conclusions are possible at the present moment in this regard.
Studies that Determined the Relationship of other Personal Qualities to Mathematical Creative Ability:

Personal qualities of potentially creative children in mathematics were investigated to facilitate identification of such individuals in the society. A number of personal qualities were considered and their relationship to creative ability in mathematics was studied.

Singh (1931) carried out a study on a sample of 90 High School Science students randomly selected from the urban and rural schools located in Sultanpur (Awadh), India. The main objective of the study was to develop an equation showing the relationship between mathematical creativity and personality dimensions of high school pupils. A test of mathematical creativity developed by the investigator was administered to the subjects to obtain the measures of their creative ability in mathematics. Measures of their personal qualities were also assessed and correlated to mathematical creativity measures. It was observed that mathematical creativity varies directly with solitary, ascendant, casual, irritable, critical, tender minded and reflective dimensions of personality. This result led to establish the equation.

\[ MC = K (\text{sol.}, \text{asc.}, \text{cas.}, \text{irr.}, \text{cri.}, \text{ten.m.}, \text{ref.}) \]

where \( MC \) = Mathematical Creativity, and \( K \) = a constant.
Further, the mean creativity scores computed for sociable, ascendant, cheerful, placid, tough-minded, reflective, impulsive, active and responsible dimensions differentiated the urban subjects from their rural counterparts. The former were found more social, responsible, placid, reflective and impulsive than the latter, whereas the latter were more ascendant, active, cheerful, accepting and tough minded than the former.

A similar attempt was made earlier by Getzels and Jackson (1958) in their study which involved two mutually exclusive groups of students enrolled in grades six through the senior year in a private high school. One of the two groups consisted of 28 subjects who ranked in the top 20% of the total sample of 500 on IQ measures but not in the top 20% on creativity indices, and was designated as "highly intelligent" group. The other group, called the "highly creative" group, included 24 subjects who ranked in the top 20% of the total sample on creativity measures, but not in the top 20% on IQ measures. A creativity battery consisting of five tests - Word association, Use for things, Hidden Shapes, Fables and Make-up problems - designed by the investigators was used to obtain subjects' creativity measures. Standardised verbal and numerical achievement tests appropriate to each grade level and intelligence tests were also used for this study. The two groups were compared on a number of
variables including the subjects' own preference for the personal qualities they would like to possess, their perception of the personal qualities they themselves believed most desirable for successful adult life and those they perceived would be most preferred by teachers in children. As to the personal qualities preferred by the subjects themselves, the highly creative group was less interested in high marks, IQ, high energy level, character and goal-directedness than the highly intelligent group. The former group attached more importance to wide range of interests, emotional stability and sense of humour than the latter. Likewise, an outstanding difference was observed between the two groups in the degree of their aspiration for success in adult life. Finally, the correlation between self-ideal and the qualities they perceived teachers would prefer in them was slightly negative in the case of the former group, but positive in the case of the latter.

2.3 Relationship of Creative Ability in Mathematics to Academic Achievement in Mathematics

The relationship between creative ability in mathematics and academic achievement in mathematics was estimated by some investigators, and diverse findings were reported. All such studies were grouped under three categories according to the degree of relationship found between the two variables. Those are:
(i) Studies that reported significant relationship between mathematical creativity and achievement in mathematics.

(ii) Studies that found moderate relationship between creative ability and achievement in mathematics.

(iii) Studies that revealed low/non-significant relationship between creativity and achievement in mathematics.

2.3-1 Studies that reported Significant Relationship between Mathematical Creativity and Achievement in Mathematics: Evans (1965), Tuli (1984), Swain (1982) and Tuli (1985) found that measures of mathematical creativity and mathematics achievement were significantly correlated. These studies are described below.

Evans (1965) estimated the relationship between mathematical creativity as measured by 16 tests developed by him and arithmetic achievement in an experimental study. Students enrolled in grades five through eight constituted his sample. He reported significant positive correlation between mathematical creativity and achievement in arithmetic.

Tuli's (1981) study aimed at estimating the relationship between mathematical creativity, aptitude for, achievement in and attitude towards mathematics using a group of nineth grade pupils selected from the high/higher secondary schools in the Punjab State (India). Balka's
CAMT provided subjects' measure of mathematical creativity and their marks in the Punjab School Board Examination served as criterion of achievement. He found that achievement in mathematics as well as academic achievement were significantly related to mathematical creativity at the 0.01 level.

Swain's (1982) study was limited to 347 nin-th class students randomly drawn from 8 secondary schools located in three districts in Orissa (India) by the technique of cluster sampling. Four mathematical creativity tests developed by Acharyulu et al (1981) were used for measuring subjects' creative ability in mathematics. Scores obtained by the subjects in three consecutive mathematics class tests were collected from the school records and the means of those three scores were taken as measures of their achievement in mathematics. The correlation coefficient between the two measures was found to be statistically significant (P < 0.01).

Tuli (1985) replicated his previous study (1981) using a sample of 439 nin-th class girls drawn from high/higher secondary schools of the Punjab State. This time also he found that achievement in mathematics was significantly related to creativity in mathematics (at the 0.01 level).

Similar findings on the relationship of general creativity to achievement in mathematics were reported by
a number of investigators.

Lanier (1967) explored the relationship between creativity, intelligence and achievement in mathematics taught by discovery method. 69 students admitted into grades IV to VI in the Oklahoma University Elementary School were the subjects in the study. The Verbal and Figural batteries of the Torrance Tests of Creative Thinking and IOWA Test of Basic Skills, Forms 3 and 4, were used to obtain measures of creativity and achievement in mathematics respectively. The results indicated a significant relationship between creativity and problem-solving category, whereas performance in other categories of ITBS were unrelated to creativity.

Borgan (1971) carried out an experiment to determine the differential effects of instructions imparted in New Schools versus other schools on creativity, dogmatism and arithmetic achievement. 215 students enrolled in grades IV through VI in New Schools and 268 students of the same grade levels admitted into other schools in a city located in Central North Dakota formed the experimental and control groups respectively. Creativity as measured by tests developed by Guilford and his associates was found to be related to achievement in arithmetic concepts, problem-solving and total arithmetic achievement measured by the IOWA Test of Basic Skills.
Pamboukian (1972) investigated grade level and sex differences in various categories of creativity as well as the relationship between creativity and performances in mathematics. 245 students (120 boys and 125 girls) drawn from grades III through VI in the Niagara Peninsula Schools, Ontario were subjects for the study. Torrance Tests of Creative Thinking, Figural Form A and Verbal Form A, provided measures of creativity for the subjects. The Seeing Through Arithmetic Test (STAT) and teachers' evaluation furnished the objective and subjective measures of performance in mathematics. Relationships between categories of creativity and categories of mathematics achievement were found stronger than composite scores of the two variables.

2.3-2 Studies that Found Moderate Relationship between Creative Ability and Achievement in Mathematics: In estimating the relative effectiveness of group versus individual study methods in improving mathematical creativity some studies reported that mathematical creativity was moderately related to achievement in arithmetic.

Spraker (1961) conducted one such study. He administered his own mathematical creativity test to seventh grade students drawn from eight classes. He reported a correlation of 0.66 between mathematical creativity and achievement in arithmetic. It was found
that subjects who scored higher in arithmetic test had higher scores on mathematical creativity test as well.

Banghart and Spraker (1963) also confirmed the finding reported by Spraker (1961). In their study, they used 180 seventh grade students whose mathematical creative ability was measured by a test developed by the researchers. The product-moment correlation between the measures of mathematical creativity and arithmetic achievement was 0.66.

2.3-3 Studies that Revealed Low/Non-Significant Relationship between Creativity and Achievement in Mathematics: Only a few studies reported weak association between the two variables. The following were some of the studies.

Mainville (1972) explored the degree of relationship between mathematical creativity and mathematics achievement. The purpose of the study was to determine the effects of Mathematics Activity Materials on creative thinking ability. The sample consisted of students enrolled in the course entitled "Elements of Mathematics I" of the University of Maine. Mathematical Creativity Tests, Forms A and B, and a Mathematics Achievement Test developed by the researcher were used to obtain measures of mathematical creativity and mathematics achievement respectively. The Product-moment correlation between the two measures revealed no significant relationship.
This finding led to the conclusion that the two tests probably measured different aspects of mathematical ability.

Keese (1972) compared the achievement in mathematics between high and low creative students selected from two intact eighth grade classes and found no significant difference between the two groups.

Jensen (1973) explored the relationship between mathematical creativity, numerical aptitude and mathematics achievement. Three intact sixth grade classes enrolling 40, 89 and 103 students respectively in three Public Schools located in Austin, Texas, were selected for this study. A mathematical creativity test, "How many questions?", the non-language section of the California Tests of Mental Maturity, and the Problem-Solving and Computation sections of the Metropolitan Achievement Tests provided measures of mathematical creativity, numerical aptitude and mathematics achievement respectively. The rank order correlation coefficients between measures of mathematical creativity and mathematics achievement were found to be low. The magnitude of the two correlations — correlation between mathematical creativity and problem-solving, and mathematical creativity and computation — was about the same.

Balka (1975) developed an instrument, consisting of
four divergent items and two convergent items, called "Creative Ability in Mathematics Test" (CAMT) to tap mathematical creativity of 500 high school pupils drawn from grades VI through VIII. To establish the construct validity of his instrument, he estimated the relationships of measures so obtained to measures of general creativity on Minnesota Tests of Creative Thinking (Abbreviated Form VII), measures of intelligence and mathematics achievement collected from school records. Performance on the CAMT was found to be related to mathematics achievement. He concluded that CAMT measured abilities different from those measured by tests of mathematics achievement, intelligence and general creativity.

2.4 Sex Differences in Mathematical Creativity

Investigations on the sex differences in creativity in mathematics resulted in conflicting findings. These studies were classified and reported under the following heads:

(i) Studies that revealed superiority of Boys over Girls in Mathematical Creativity,

(ii) Studies that reported the superiority of Girls over Boys in Mathematical Creativity, and

(iii) Studies that found no sex differences in Mathematical Creativity.
2.4-1 Studies that Revealed Superiority of Boys over Girls in Mathematical Creativity: The following studies found that boys were more creative in mathematics than girls.

Tuli (1982) compared the mathematical creative abilities of 172 boys and 132 girls randomly drawn from class IX of high/higher secondary schools in Punjab (India). He translated Balka's (1975) CAMT into Hindi and used it to obtain measures of mathematical creativity of the sample. Differences in fluency, flexibility, originality and composite mathematical creativity scores between boys and girls were found to be significant at the 0.01 level, and the differences were in favour of boys.

Swain (1982), too, observed sex differences in mathematical creativity. The sample for his study consisted of 150 boys and 150 girls of class IX drawn from 8 high schools in Orissa (India). A Mathematical Creativity Test developed by Acharyulu et al was used for this study. The results indicated significant differences between boys and girls in respect of their mean fluency, flexibility and composite creativity scores. All the differences were statistically significant at the 0.01 level and the differences were in favour of boys. Although the differences in the mean originality scores for the two sexes was not significant, the boys were superior to girls.
2.4-2 Studies that Reported the Superiority of Girls over Boys in Mathematical Creativity: Evidence for girls' superiority in mathematical creativity was furnished by the following studies.

Prouse (1965, 1967) reported the same results from his studies which were undertaken to tap potentially creative pupils in mathematics from among 312 seventh graders and to explore the relationship between their mathematical creativity and other abilities and interests. A Mathematical Creativity Test, a Subject-Preference Survey, and a form for teacher-rating of students as creative were designed by the investigator and used in the study. Two of Guilford's Tests - Number Rules and Match Problems V - were also administered to the subjects. A comparison of the mean mathematical creativity scores of boys and girls revealed that girls were more creative in mathematics than boys.

Jensen (1973) conducted a study to discover the relationship between mathematical creativity, numerical aptitude, and mathematical achievement. 232 students of three intact sixth grade classes in three public schools located in Austin, Texas were the subjects in the study. In all the three schools, girls excelled boys in mathematical creativity.

2.4-3 Studies Reporting No Sex Differences in Mathematical Creativity: The conclusion that sex is unrelated
to creative abilities in mathematics was derived by Evans (1965) on the basis of the findings of a study on students of grades V through VII. Sixteen tests developed by him provided measures of mathematical creativity of the subjects. This study revealed no significant differences between boys and girls. However, at the seventh and eighth grade levels, the girls' performance on a few tests was found significantly better than that of boys.

No sex-related differences in general creativity were reported by Pamboukian (1972) and Borgen (1971). While the former was interested in discovering the differential development in creativity at grade levels Three to Six, and the relationship of creativity to achievement in mathematics, the latter estimated the differences in creativity and dogmatism of students enrolled in grades Four through Six in two different types of schools and the relationship of creativity and arithmetic achievement. The Torrance Tests of Creative Thinking, Figural Form A and Verbal Form A were used by the former, whereas the latter used the creativity tests developed by Guilford and his associates to measure creative abilities of their subjects.

2.5 Rural-Urban Differences in Creative Ability in Mathematics:

Studies which investigated the rural-urban differences
in mathematical creativity were grouped under the following two categories.

(i) Studies which found significant Rural-Urban Differences in Mathematical Creativity.

(ii) Studies which reported no Rural-Urban Differences in Mathematical Creativity.

2.5-1 Studies which found Significant Rural-Urban Differences in Mathematical Creativity: Some investigators reported that Rural-Urban localities had differential effects on Mathematical Creativity. Their findings were given below.

Swain (1982) studied the rural-urban difference in mathematical creativity using 150 rural and 150 urban class IX students randomly selected from 8 high schools of Orissa (India). The differences in the mean fluency, flexibility and composite mathematical creativity scores as measured by a mathematical creativity test developed by Acharyulu et al between the rural and urban groups were found to be statistically significant at the 0.01 level, and the differences were in favour of urban subjects. Although the mean originality score of the urban group was higher than that of the rural group, the difference was not statistically significant.

Tuli (1982) also studied the rural-urban difference in creativity in mathematics using a group of 78 pupils
of above-average developed region and 37 pupils of under-developed area enrolled in class IX in high/higher secondary schools in the State of Punjab. The mathematical creativity scores for both the groups were provided by the Hindi version of the GMT developed by Baika (1975). It was found that the differences in the means of fluency and flexibility scores of the two groups were statistically significant, and the differences favoured the subjects belonging to under-developed region. But the subjects representing the developed region excelled their counterparts in the under-developed area in mean originality score, and the differences between the two groups was significant at the 0.01 level. However, a comparison of the mean composite creativity scores for the two groups could not establish significant rural-urban difference in mathematical creativity.

2.5-2 Studies which reported No Rural-Urban Differences in Mathematical Creativity: The following studies found that Mathematical Creativity was not significantly influenced by Rural-Urban difference.

Castle's (1965) study, which estimated the difference in creative thinking ability of rural and urban students, found that rural-urban variation had no significant effect on mathematical creativity. 87 pupils enrolled in grades IX through XII in two junior and senior high schools, one located in a rural area (Canute, Oklahoma) and the other in the city of Oklahoma, were the subjects.
in the study. The urban students were selected by pairing them with the rural students on the basis of intelligence, age, sex and grade classifications. The Creativity Tests developed by Getzels and Jackson (1958) provided the measures of creativity for the subjects. Comparing the mean creativity scores of the rural and urban subjects it was found that rural-urban locale did not affect creative abilities.

Singh (1981) studied the rural-urban difference in mathematical creativity. His sample consisted of 90 high school students drawn from both rural and urban areas of Sultanpur district, Awadh (India). He used his own test of Mathematical Creativity in the study. No significant difference in the mean mathematical creativity scores between the rural and urban subjects could be found. The rural subjects, however, had higher mean mathematical creativity score (M=147.7) than that of their urban counterparts (M=129.5).

In summary, it may be said that studies on the Mathematical Creativity of high school students were very few and the findings reported were conflicting. The tests used for obtaining measures of mathematical creativity were mostly developed by the investigators themselves and the reliability and validity of these have yet to be established firmly. The extent to which measures of mathematical creativity differ from measures of general
creativity and the extent to which those identified as highly creative on the Mathematical Creativity Tests would become really creative mathematicians later in their life need to be studied more rigorously than now. Mathematical Creativity and its relation to different school related variables have yet to be explored more thoroughly and the present study is an attempt in this direction.