

Chapter 6

FINDINGS, DISCUSSIONS AND SUGGESTIONS

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FINDINGS, DISCUSSIONS AND SUGGESTIONS

6.1 INTRODUCTION

In this chapter, the investigator has discussed the findings based on the major errors committed by the students in geometry, which were derived from the analysis of the achievement test. The learning difficulties of the students in geometry have also been identified and presented. This is followed by the discussion under various contexts related to the present study. Finally, the suggestions for students, teachers and parents to help students to improve and enhance their achievement in geometry and for further researches are presented.

6.2 MAJOR FINDINGS AND CONCLUSIONS

From the data analysis and interpretation major findings and conclusions based on the present study were drawn out and were categorized by the investigator as under:

6.2.1 Findings based on Achievement Test

The investigator collected the data through the achievement test of geometry. Major findings based on the analysis of the responses of the students in achievement test of geometry are as follows:

- Only fifty-seven students out of 258 i.e. about twenty-two percent students could achieve more than 60 percent in the achievement test of geometry. Also, the mean score was 45.5 which is less than fifty percent. So in general the achievement of the students in geometry was not good.
- Out of hundred items in only ten items it was observed that more than seventy percent of students gave correct response. All the items were either of knowledge or comprehension level. It was inferred that the students performed well in the following areas:
 - The postulate of line “Every line has atleast two distinct points.”

- Collinear points
 - Mid-point of the line-segment
 - Initial point of the ray
 - Postulate of plane "Three non-collinear points determine one and only one plane"
 - Bisector of an angle
 - Line is a subset of plane
 - Coplanar points
 - Equality of angles
- Out of hundred items in the achievement test in ninety items the performance of the students was not good. The performance on the items was categorized as satisfactory (between sixty to seventy percent), moderate (between fifty to sixty percent) and poor (below fifty percent). The description about the categorization of the performance of students based on the errors committed by the students in particular area of geometry is given below.

I. Students performed satisfactorily but still quite a few students committed errors in the following areas:

Equality of lines, Relationship between point and line, Collinear and non-collinear points, Congruent line-segments, Concept of ray, $\overline{AB} \subset \overrightarrow{AB}$, Equality of planes, Measure of an angle, Interior of an angle, pair of supplementary angles, coplanar points, Closed half plane, Vertically opposite angles are congruent.

II. Students performed moderately and many students committed errors in the following areas:

Concept of line, Betweenness of points, End-points of line-segment, Intersection of two planes, two congruent line-segments on a number line, four collinear points, three lines intersecting in one point, property of distance " for P-V-T, $PV+VT = PT$ ", Skew lines, Not equal angles.

III. Students performed poorly and most of the students committed errors in the following areas:

Intersection of two lines, the property " $PQ+QR \geq PR$ " for three distinct points P,Q, and R, Opposite rays, Bisector of a line-segment, Line is a subset of plane, Intersection of two half planes, Cross-bar theorem, Supplementary and Complementary pair of angles, Partitions of plane by an angle, Concept of distance, parallel lines, Intersection of line-segments, Intersection of a line and a line-segment, Parallel planes, Concept of an angle, Interior and exterior of an angle, Vertically opposite angles, linear pair of angles, Types of angles, Relationship between point and line, Intersection of rays, Relationship between point, line, line-segment and ray, Intersection of ray and line.

The above listed are the weak spots identified where the students commonly commit errors in geometry.

- Students committed maximum errors i.e. about seventy-two percent in the items based on the geometrical figure of the number-line, distance and betweenness. Also, it was seen that the students committed more errors i.e. about sixty-seven percent in case of representing the given geometrical statements with the help of a figure as it involves all the fundamental concepts collectively (Table - 15).
- It was found that on average students committed about forty-five percent errors at knowledge level, about fifty-four percent errors at comprehension level and about sixty-four percent errors at application level. It was observed that maximum errors were committed by the students in case of the items related to application level and minimum errors in case of items related to the knowledge level (Table - 16).

6.2.2 Findings Based on the Diagnosis of Learning Difficulties

The investigator collected the data through the diagnostic test of geometry. Major findings based on the analysis of the responses of the students in diagnostic test of geometry are as follows:

- The learning difficulties related to the very fundamental understanding about the geometrical concepts were identified broadly which resulted in other learning difficulties. They were as listed below:
 - No clarity about defined and undefined terms
 - The basic concept of different geometrical terms was not understood. There was confusion in the different geometrical terms viz. Point, line, line-segment, ray, Plane and Angle.
 - Difference between the geometrical representation and the geometrical figure for line, line-segment and ray was not understood
 - The concept of the geometrical figures in terms of set of points was not understood and the intersection of any two sets was not understood
 - The geometrical representation and the symbols used for all the geometrical concepts viz. point, line, line-segment, ray, Plane and Angle was not clear
 - The relation of all the geometrical terms in terms of their set formation and subset of each other was not understood. Thus the intersection of line, line-segment and ray in different combinations was a difficulty.
 - For the geometrical terms (line, line-segment and ray) only the points which are named are considered as a part of it, apart from these named points there are infinitely many points on them was not understood
 - The relation of point, line and plane was not understood
 - The difference between line and plane was not understood
 - Different types of angles were not understood

- Difference between different types of pair of angles and its interrelation was not understood.
- The learning difficulties were analyzed in detail and were categorized topic-wise from that the basic ones are collectively presented as below:
 - There is only Equality of two lines was not understood
 - Each point lie on some line was not understood
 - The concept of line extended infinitely on both the sides was not clear
 - One & only one line passes through two distinct points as line is determined by two distinct points was not understood
 - Differences between parallel, lines, equal lines, distinct lines, intersecting lines and skew lines were not understood.
 - Differences between the collinear points and coplanar points, non-collinear and non-coplanar points were not understood and how the context of point with respect to plane and line is different was not clear.
 - Line divides the plane in three parts was not clear and line itself is the third partition of the plane along with two half planes was not understood.
 - Line-segment can never be equal to a line and difference between line and line-segment was not understood.
 - Not clear that line-segment is not just end-points but is a set of all the points in between A & B including A & B.
 - The set representation of the line-segment was not understood. The difference between the set representation of line-segment & ray was not understood.
 - The concept of ray that its extended infinitely on one side was not clear and the end-point / initial point is included & is part of ray was not clear.
 - The difference between \overrightarrow{AB} & \overrightarrow{BA} is not understood.

- Difference between "Distinct rays" & "Opposite rays" was not understood
- The significance of all the three conditions to be satisfied simultaneously for the opposite rays was not understood viz. both the rays lying on the same line, having same initial point and are in opposite direction.
- Intersection of two lines is either a point or an empty set was not understood.
- Intersection of two line-segments can be a line-segment or a point but can never be a line or ray was not understood.
- Intersection of two rays can never be a line but is either a point or line-segment or ray was not understood.
- Difference between the intersection of two distinct lines and two distinct planes was not clear i.e. intersection of two lines is a point and that of two planes is a line.
- Intersection of two rays can never be a line but is either a point or line-segment or ray was not understood.
- Distance / Length of the line segment is always positive was not clear and for finding the length of the line-segment the values of two points is to be subtracted & the modulus is to be considered was not understood.
- The difference between the points on the number-line and the values associated to the points on the number line was not clear i.e. Alphabets represents points and the numbers are the values associated to the points.
- The concept of plane and the postulates related to plane were not understood. i.e. three non-collinear points determine a plane then the significance of non-collinearity was not understood, two distinct lines determine a plane was not understood.
- An angle is made up of two rays having same initial point and not lying in the same line was not understood.

- The difference between $\angle QRS$ & $\angle RQS$ was not understood. Also the equality of two angles was not clear.
 - There are in total 3 partitions of plane made by an angle was not understood. There was confusion in the three partitions of plane made by an angle.
 - Difference between Complementary angles and Supplementary angles was not clear.
 - Difference between Linear pair of angles, Adjacent angles, vertically opposite angles, Supplementary angles, Congruent angles and their interrelation was not understood.
 - The appropriate use of symbols to express the relation of point and line, line and line-segment, line and plane, ray and line, ray and line-segment was missing, i.e. No clarity about the correct use of $\in, \notin, =, \neq, \subset$
 - The meaning and difference between the symbols $\in, \notin, =, \neq, \subset$ was not understood.
 - Naming of points on the line / line-segment / ray was not understood
 - one point represented by 'A', 'B', 'C' in a plane or on a line was not clear
- Also there were many misconceptions held by the students related to the fundamentals of geometry which are listed below.
 - When point is on the line, then point was considered as a subset of line
 - When point is not on line, then point was considered as not equal to line
 - Rays with same initial point towards two distinct points in the same direction from the initial point were considered to be not equal rays
 - Rays with different initial points but extended towards the same point are considered as same rays
 - For two points A & B on the line ℓ , \overline{AB} was considered as $\overline{AB} \in \ell$

- For two points A & B on the line ℓ , \overleftrightarrow{AB} was considered as \subset of ℓ
- For two points A and B, $\overleftrightarrow{AB} = \overleftrightarrow{BA}$ was considered
- For B-A-Y, $\overleftrightarrow{BA} \neq \overleftrightarrow{BY}$ was considered
- For B-A-Y, $\overleftrightarrow{BA} \subset \overleftrightarrow{BY}$ was considered
- For D-B-A, $\overleftrightarrow{DA} = \overleftrightarrow{BA}$ was considered
- Three points lying on three distinct lines are collinear
- Point lying between two parallel lines is the point of intersection
- The intersection is part in between two lines
- In the betweenness relation of the points the in between point is an initial point & other points are forming rays with respect to that point
- The right most point on the line was considered as the origin of the number-line
- Rectangle is the intersection of two planes
- Supplementary angles are congruent
- the line passing through both the lines is the intersection of the two lines i.e. The transversal is the intersection of the two parallel lines
- The line which intersects the two lines, the set of those intersecting points is the intersection of the two lines
- Set of all the points named either on the line of intersection was considered as intersection of the two lines
- Set of all the points named either on \overleftrightarrow{CB} or \overleftrightarrow{CA} is the intersection of the two line segments \overleftrightarrow{CB} and \overleftrightarrow{CA}
- For C-B-A, $\overleftrightarrow{CB} \cap \overleftrightarrow{CA}$ is the point in between C & A i.e. B is considered as intersection
- The two lines of which the two line-segments are subsets is the intersection of the line-segments
- A line passing through both the rays was considered as intersection of the rays
- The line on which both the rays lie was considered as intersection of two rays

- The left most point on the line was considered as the origin of the line
- The right most point on the line was considered
- Points lying on any line in the plane were considered as co-planar points
- For $\angle DEF$, \overrightarrow{DE} & \overrightarrow{DF} are arms of an angle
- For $\angle DEF$, D is a vertex of an angle
- For \overrightarrow{PQ} & \overrightarrow{PR} , the angle formed is $\angle PQR$

6.2.3 Findings Based on the Remediation of the Learning Difficulties

The impact of remedial programme was studied by comparing the pre-test scores and post-test scores of the students of experimental group. Also, the performance of the students of experimental group on each item in achievement test and parallel test was compared. Finally, the ANCOVA was applied on the scores of control group and experimental group to study the impact of the remedial programme. The findings related to the remediation of the learning difficulties were revealed as follows:

- The mean score of the students of experimental group on the pre-test was 36.25 and the mean score of the students on post-test was 59.03 which showed the improvement in the performance of the students. i.e. the performance of the students has increased from mean of 36.25 in achievement test to mean of 59.03 in parallel test for achievement. Thus, there is observed difference of 22.78. Also, the minimum gain in terms of individual student was of nine percent and the maximum gain was of forty-three percent.
- The remedial programme resulted in the shift of the frequency distribution from the low scores to the high scores in the achievement in geometry. In the pre-test maximum students scored between twenty-one and thirty percent where as in case of post-test maximum students scored between fifty-one and sixty percent. It was also found

that in the pre-test no student scored more than sixty percent except one where as in the post-test there were thirteen students who scored more than sixty percent, three students scored more than seventy percent and two students scored eighty percent and above.

- From the comparative analysis of the correct responses for each item in the pre-test and post-test it was observed that for any of the item in the achievement test and parallel test the number of correct responses have not decreased it has either increased or at the most remained the same. So, it can be concluded that overall there was a gain in the item-wise performance.
- It was found that there was increase in the performance at each level of instructional objectives. The gain in case of knowledge, Comprehension and Application level of objectives was about nineteen percent, about twenty-one percent and twenty-nine percent respectively. At the same time it was also observed that the performance at application level has not exceeded the performance at comprehension level and the performance at comprehension level has not exceeded the performance at knowledge level (Table - 21). The maximum gain was at application level which is the result of the gain at knowledge and comprehension level. It was observed that if the performance at knowledge and comprehension level is increased then it has cumulative impact on the increase in the performance at application level.
- Finally, it was found that there was a significant difference between the mean scores of the control group (46.88) and the experimental group (59.03) and it is towards the mean score of the experimental group. Hence, the diagnosis and remediation has a positive impact on the achievement of the students of experimental group. It was found

that the remedial measures helped the students to reduce the learning difficulties and achieve better in geometry.

- During the process of remediation various interactive methods and teaching materials were used. It was found that students were interested in the process of learning as they got the opportunity to share and discuss their own learning. This was also expressed by the students during the open session conducted towards the end of the remedial programme. Also, the discussion before the remedial measures many a times gave an insight to the misconceptions hold by many of the students related to the basic concepts of geometry. These misconceptions were addressed during the remediation and were clarified, which helped students to achieve higher level of objectives of learning.

6.3 DISCUSSION

Since ancient period to today's technological world, Mathematics has always been at the center of any development. Mathematics as a discipline has a specific nature that makes it different from other discipline. It's a Science but abstract in nature. Its abstractness is experienced by the students through the study of three basic branches of Mathematics viz. Arithmetic, Algebra and Geometry. Initially the experiences provided to the students for studying mathematics are concrete and then they are to be extended to the abstract understanding related to the concepts of Mathematics. Geometry is a branch which involves the abstractness in terms of Spatial relations, Visualization, imagination and the symbolic representations.

As all the branches of mathematics are interrelated and the learning of mathematics is a holistic process and it is hierarchical. At the same time as found by many studies the error committed by the students and the learning difficulties faced by students are also hierarchical in terms of the number and the complexity. So, it's important to make sure that at the fundamental level

only the learning difficulties faced by the students are identified and remediated.

The present study found that the achievement of the eighth standard students in geometry is not good and students committed many errors in the basics and fundamentals of geometry. This restricted the achievement of the students in geometry. The mean score was 45.5 which is less than fifty percent on the achievement test of geometry. Similar findings of low achievement in high school were cited by the Indian and foreign studies, Sharma (1978), Sashidharan (1992), Kasat (1991), Jain and Burad (1988), Rastogi (1983), Jain (1979), Bhirud (1975), Ashar (1972), S.I.E. Guj (1969), Sjostrom (2000), Winter (1991), Lee (1999), Aviles (1989), Sangtong (2000).

Bhardwaj (1987) found that the error rate at middle standard in all the three areas that is arithmetic, algebra and geometry came out to be 30.4 percent, 50.6 percent and 51.4 percent respectively and there was a significant improvement in achievement of the students after they had gone through the remedial exercises. Patel (2007) found that Geometry was most difficult for students while algebra and statistics were equally difficult. During the present study it was also observed by the investigator that students faced more difficulties in geometry and could not perform well. Students committed many errors in attempting the test items they were lacking in the visualizing ability and the abstract understanding of the geometrical concepts.

The responses of the students in the diagnostic test illustrated the learning difficulties faced by the students in answering the questions in geometry correctly. The major difficulties were related to the lack of clarity about the basics and fundamentals of geometry. Students faced difficulties in acquiring the knowledge of different geometrical symbols and statements, in understanding about different geometrical terms and concepts. The reasons for the learning difficulties faced by the students may be faulty or not

appropriate method of teaching or the lack of attention on the students' actual learning about different geometrical concepts, or lack of diagnosis and remediation by the teacher. It was found that students had the rampant misconceptions related to the fundamental concepts of geometry which leads to the common errors committed by the students. This results in the cumulative effect on the errors committed by the students and restricts the level of learning of the students. Most of the students performs geometry at knowledge level i.e. memorizing the definitions, postulates, theorems and results but the real understanding of the geometrical concepts is missing so the performance at comprehension level and application level is poor. This has been supported by Sashidharan (1992), Manika (1983), Rastogi (1983), Sarangapani (1990) that mathematics being a hierarchical subject, errors in the understanding of lower concepts hampers the conceptualization of higher concepts.

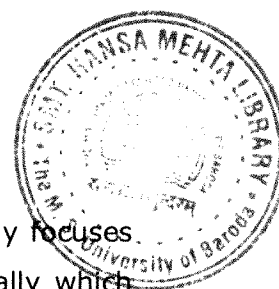
The need for remedial programme was observed on the basis of the performance of the students in the diagnostic test. The remedial programme was carried out through different classroom activities; the abstractness was related with the concrete examples. Also, the level of involvement of students was more with the help of different group activities and discussions. During the remedial programme it was observed that students were interested in learning geometry and were enjoying the process as different teaching methodologies and various teaching learning materials were used. Kothari (1985) found that students enjoy studying through the media which is activity oriented. Mishra (1998) found that effective utilisation of Teaching learning material results in the better achievement in mathematics. Shashikala Devi (1987) found that explaining, eliciting through questioning, teacher's working out model problems, black board work, independent work by the students, giving individual guidance, providing feedback and giving assignments were the important and most often used ingredients of effective teaching. It was suggested that Teacher's training programme should train teachers in specific skills which are found to characterize effective

mathematics Teaching, the black board work, giving graded drill problems, making the students do independent work giving individual guidance and providing feed back. Steele (2006) suggested that teachers can grow in their knowledge of content and pedagogy through practice-based teacher education experiences.

The present study has shown the positive impact of the remedial programme on students' learning and achievement in geometry. This is inline with all the studies based on Diagnosis and Remediation in Mathematics that has shown the positive effect on learning of mathematics amongst the students Das and Barua (1968), S.I.E. Guj. (1969), Bhattacharya (1982), Bhardwaj (1987), Dutta (1990), Gurusamy (1990), Viswanathan (1997), Warute (1998), Venkateshwarlu (2001), George (2003), Ward (2001).

The present study shows the low achievement in geometry and prevalence of misconceptions in geometry at eighth standard. There has to be rethinking about what students learn from mathematics and how it benefits them. The educational system has to fulfill its moral responsibility of ensuring the achievement of objectives related to learning of mathematics and live a productive life. Periodic monitoring of the progress of students, identifying the learning difficulties, and helping students to overcome those should be an integral part of the school education. In order to do this the system has to revamp its teaching methods and include some important components in the teaching-learning process based on the evidences and the researches.

According to NCTM (2000), the basis for Standard 2000 (set of standards for the mathematics curriculum) are the set of core beliefs about students and learning mathematics: (i) every student deserves an excellent programme of instruction in mathematics that challenges them to achieve at the high level required for productive citizenship and employment, (ii) Learning mathematics is maximized when teachers focus on mathematical thinking and reasoning and (iii) Learning mathematics is enhanced when content is



placed in context and connected to other subject areas. This clearly focuses on achieving the goal of training pupils to think and reason logically which aims at the utility of mathematics for the learner. Also, the present study demonstrated about the achievement of higher level of objectives after the remedial programme where students were involved in thought provoking process of learning mathematics through group discussions and group activities.

6.4 SUGGESTIONS

The research scenario of mathematics education is not very different from other subjects in terms of the boom of research activity period i.e., 1970 onwards. Fourth Survey of Research in Education (1991) and Fifth Survey of Educational Research (1997) have very elaborately discussed about the research scenario of mathematics education. Mathematics, being at the core of the educational process needs to be more researched. The investigator attempts to put forth certain suggestions for mathematics education and research in mathematics education. The suggestions are at three different levels viz. teachers and teaching of mathematics, learners and learning of mathematics and further researches in mathematics education.

6.4.1 Teachers and Teaching of Mathematics

- Teaching of mathematics has to bring in variations with respect to the topic and emphasis should be on understanding of the method. There should be discussion about the errors committed rather than mere correction.
- There should be a paradigm shift from rote memorizing, drill and practice to constructing knowledge based -on one's own experience. Teacher should make mathematics relevant to the learner by taking into account learners' thinking, representations, notations.
- Teachers should make efforts to reduce teacher-dependent learning situations. Instruction based on rules, memorisation, algorithmic

presentation which concentrated on correct answers and neglected cognitive thought processes should be avoided.

- The teachers need to reflect upon the objectives drawn for teaching of mathematics. Rather than teacher being the centre of the knowledge and a necessary component for successful task completion, student should become confident in their skills, transfer their skills to novel situations, apply higher level thinking to novel situation without teacher help.
- Teachers have to review one's own teaching. Whether sufficient time is spent on student responses, how much of student independence is being encouraged, are the student becoming active participants, how much time is spent on single student during class-work.
- Instead of transacting the content the focus should be on the actual learning of the students. Prolonged periods of lecture by the teacher should be avoided and students should be given an opportunity to think and share their ideas.
- The rapport should be developed by the teachers with the students where students feel comfortable sharing their answers without the fear of being incorrect.
- While evaluating student's responses in the answer-sheets or notebook exercises teacher should focus on the errors committed by the students, the causes for the errors and the misconceptions of the students.
- Teachers should conduct the diagnostic test after the completion of each unit based on the instructional objectives of that unit, in order to identify the students having learning difficulties and the learning difficulties faced by them related to the particular unit.
- Teachers should identify the learning difficulties faced by the students in terms of acquiring knowledge and understanding the concepts in mathematics. This should be followed by remediation of the learning difficulties in order to take students to higher level of thinking.

- Teachers should provide remedial measures to the students through teaching aids, group activities and small group teaching. So that the students can experience the abstract nature of mathematics through manipulation of the concrete objects, develops sound understanding about the mathematical concepts, are able to overcome the learning difficulties and move ahead in learning of mathematics.
- Error identification, Diagnosis and remediation of the learning difficulties should be the integral part of the teaching of mathematics. It can be integrated with the internal evaluation viz. unit tests or terminal examinations.
- Specially, in case of geometry, teachers should develop some teaching material for the remedial programme that provides an opportunity to the students to visualize the two-dimensional and three-dimensional figures from different angle and gives enough practice to the students. This will help students for better understanding and will develop the visualization ability of the students, which is important for the learning of mathematics.
- Teachers should conduct a test in the beginning of the class eighth to check the entry behaviour of the students, as this is the induction phase of the students to the secondary education. Also this test should take into consideration the identification of the learning difficulties of students in the basics and fundamentals of mathematics. The learning difficulties should be remediated at the initial phase so that later on it does not hamper the higher learning of mathematics.
- Teachers should be provided with diagnostic tests and also trained to construct diagnostic tests. Remedial programmes are not mere repetition of class-work instead teachers should identify the weak areas and should clarify the basic concepts to the students by some group activities and discussions. Teacher should try to make the subject interesting by using the teaching aids, mathematical models and manipulatives.

6.4.2 Learners and Learning of Mathematics

- Learners should have a positive attitude towards the learning of mathematics and should have self motivation for achieving better in mathematics.
- Learning of mathematics is not just memorization of the definitions, rules, formulas, postulates and theorems but it is a training in the logical reasoning ability and development of thinking abilities.
- Learners should ask question of how and why types at each and every step in mathematics and should not proceed without understanding in mathematics as it will hamper further learning of mathematics.
- Learners should express their ideas related to their understanding in mathematics freely in front of the class and teacher as in the process their doubts are clarified.
- Learners should not leave their doubts and queries in mathematics unanswered. Infact, they should approach the mathematics teachers for clarifying their doubts in mathematics and their achievement in mathematics is improved.

6.4.3 Further Study

- Similar type of study can be conducted for algebra and arithmetic at secondary and higher secondary level
- Similar type of study can be conducted for other school subjects.
- A case study can be conducted for the considerable weak students in mathematics and accordingly individual instructional programme can be provided and its effectiveness can be measured.
- An Instructional Material can be developed as a remedial measure for the weak and low achieving students in mathematics and its effectiveness can be measured.
- A standardized diagnostic test can be constructed for different areas of mathematics viz. Arithmetic, Algebra, Geometry, etc. and at different levels by establishing its validity and reliability.

- A strategy for helping students achieve high based on continuous diagnosis and remediation of students learning difficulties can be developed for the different topics of Geometry, Arithmetic and Algebra.
- Studying about the mathematical concepts where students commit maximum errors and identifying the causes for errors.
- Investigating about the concept formation of concepts with maximum difficulty
- Cross-sectional study about the teaching methods adopted for specific concepts and locating reasons for lacunae in concept formation.
- Use of various strategies and technology to enhance motivation among low-achievers in mathematics.

It is hoped that the present study will not only provide the basis for further research but will also give more effective guidelines to solve the problems of low achievers in mathematics by eliminating the learning difficulties faced by them.