CHAPTER III

METHODS AND MATERIALS
Chapter-III

Methods and Material

As discussed earlier the present investigation aims to investigate the present scenario of mathematics education at school based on examination results, teachers’ competency and parent’s awareness through application of fuzzy logic and basic statistics. Besides, it is also attempted to analyze the mathematics course curriculum on the background of students’ performance. Finally, the shortcomings, if any, will be identified based on the analysis of the results. It has been realized that a systematic study procedure is to be followed to achieve the objectives. In this Chapter the procedure of study is elaborated. The contents of this Chapter are:

- Selection of study area
- Selection of School
- Coding of schools & collection of information from selected schools
- Assessment of performance based on HSLCE and Annual Examination Results
- Assessment of performance based on Mathematical Ability Test (MAT) and Annual Examination results
- Analysis of course curriculum on the background of MAT performance
- Design and assessment of Educational Environment (EE)
3.1 Selection of study area

The present study covers the secondary school level mathematics education under Board of Secondary Education, Assam. There are about 5,396 schools providing secondary education spread over 23 undivided Districts of Assam. A study covering the entire state would be voluminous. Thus, it has been intended to consider the schools within a single District. The reason of considering the District is that it is under a single administrative unit. Moreover, it is anticipated that the District would cover large number of schools with variations in respect of (a) managerial status (i.e. Government, Provincialized, Recognized, Non-recognized and Private), (b) socio-economic conditions (urban, rural and char area), (c) parent’s occupation (farmer, employed, unemployed) and (d) education levels of parents.

Performances of HSLCE conducted for the students of 10\textsuperscript{th} standard have been considered for selection of the District. The description of the HSLCE and logic to select the study area on the basis of this test are discussed below.

3.1.1 Description of HSLCE

HSLCE is conducted by The Board of Secondary Education, Assam and is approved by the Government of Assam (India). A number of subjects including
science, mathematics, social studies, language etc are included in this test. HSLCE is the most comprehensive and uniform test for the 10th standard in Assam. The examination is conducted under different zones earmarked by the Board as per the pre-fixed schedule, which is uniform all over the state. HSLCE pass percentages of the school are considered as an indicator of general performance of school. However, the requirement of the present investigation is to use the performance in mathematics as the criteria of selection. As HSLCE results do not fulfill such requirements, efforts were made to search for a standard mathematics test having reflection on HSLCE results. The state level Mathematics Olympiad (SLMO) was identified as such a test provided HSLCE reflection criteria could be fulfilled. The description of SLMO and test to investigate reflection criteria through application of Fuzzy logic proposition are discussed below.

3.1.2 Description of SLMO

The state level Mathematics Olympiad (SLMO) is a test on mathematics subject only conducted by a leading and reputed non-governmental academic group (Assam Academy of Mathematics, Assam) of the state of Assam. Assam Academy of Mathematics (AAM) is an organization working in Assam (India). National Board for Higher Mathematics (NBHM) under Department of Atomic Energy, Government of India has recognized the state level Olympiad organized by the AAM as a standard test. The competition results of the AAM could be tools for any academic investigation. The objective of this test is to identify and
encourage talented students in different regions of the state. The test is conducted at different levels. However, test conducted for students of class X has only been considered for the present study.

3.1.3 Tools for analyzing the reflection criteria

A District is a major administrative unit of the state. Most of the developmental indices (social, economical, academicals etc) are measured at district level. Planning and programme implementation are carried out considering districts as the major units. Therefore, outcome of the present study would be useful if analyzed on the basis of district. Moreover, district wise results are easily available. Therefore, the district wise pass percentages of HSLCE have been collected for the seven consecutive years starting with the year 2000 covering all the 23 districts. The average pass percentage during these seven years of a district has been considered as the HSLCE performance indicator of that district.

The number of students qualifying SLMO from 23 districts of Assam during the same period of references (2000 to 2006) is taken for the present study. It is assumed that the whole population appearing HSLCE examination during the respective period of reference was provided a chance to appear the SLMO. The sum total of qualifying candidates during the seven years (2000 to 2006) for a particular district has been considered as the SLMO performance indicator of that district.
3.1.4 Application of fuzzy logic to select the Districts

It has been intended to select a district with some satisfactory level of performance in mathematics. However, such indicators of the Districts are not readily available. As mentioned earlier, district wise HSLCE pass percentage results are available which is indicative of all subjects. On the other hand SLMO is indicator of mathematics, and test should be made to examine whether the HSLCE examination performances of the districts are fully reflected by general performance in mathematics (i.e. SLMO performance). On the basis of such test the sample District could be selected as discussed below.

3.1.5 Formulation of fuzzy logic proposition

Fuzzy logic is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic. While classical logic deals with propositions that are just true or just false, fuzzy logic deals with propositions known as fuzzy propositions, the truth-value of which is a matter of degree. The degree of truth of each fuzzy proposition is expressed by a number in unit interval [0, 1]

For the present study a conditional and unqualified proposition has been used. A proposition may be conditional or unconditional as well as qualified or unqualified. Conditional propositions are assertions that are in conditional if-then
form, i.e. propositions that are qualified as an if statement. Both of conditional and unconditional propositions may be qualified or unqualified.

A proposition is said to be qualified if its truth-value is qualified by any modifying expressions. General form of an unqualified proposition P is as follows:

\[ P: 'X is A' is true. \]

Where \( X \) is a variable that takes specific values \( x \) from a universal set of possible values and \( A \) is some property, or predicate, attributed to the variable.

If the word ‘true’ is replaced by ‘very true’, ‘fairly true’ etc, then the proposition is regarded as truth qualified and it becomes a qualified proposition. The linguistic expressions very true, fairly true etc. are called truth qualifiers. Each truth qualifier is characterized by a function from \([0, 1]\) to \([0, 1]\).

The general form of used proposition is as follows:

\[ P: \text{If } x \text{ is A then } y \text{ is B} \ldots \ldots \ldots (3.1) \]

Where \( x \) and \( y \) are variables whose values are in sets \( X \) and \( Y \) (universes of discourse) respectively; \( A \) and \( B \) are relevant predicates represented by fuzzy sets.

The proposition can be interpreted as \( y \) is a member of \( B \) to the degree that \( x \) is a member of \( A \). If the antecedent is true to some degree of membership, then the consequent is also true to that same degree.

The above “if-then” proposition, which is assumed to be simply true, is known as conditional and unqualified proposition. And it is actually of the following form:

\[ P: 'If x is A then y is B' is true \ldots \ldots \ldots (3.2) \]
If ‘x is A’ and ‘y is B’ are represented as $A(x)$ and $B(y)$ respectively, then the proposition (2) is written as:

$$P_{x,y}: \text{‘If } A(x)\text{, then } B(y)\text{’ is true}.$$

(3.2a)

For each $x \in X$ and each $y \in Y$, the Lukasiewicz implication $I$ is used to determine the degree of truth of the conditional proposition by the rule,

$$T(P_{x,y}) = I [ A(x), B(y)] = \min [1, 1 - A(x) + B(y)]$$

[G. Klir, Y. Bo.]

3.1.6 Application of conditional and unqualified proposition for the present study

To investigate the reflection of SLMO performance on HSLCE performance of each of the districts, a conditional and unqualified fuzzy proposition of the specific form mentioned below is considered.

$P$: If “district SLMO performance” is satisfactory, then the “district HSLCE performance is high”.

The concepts of “district SLMO performance is satisfactory” and “district HSLC performance is high” are expressed respectively by the fuzzy sets $A$ and $B$ (Eqs. 3.1, 3.2 and 3.2a). Here, SLMO performances of the districts are considered as $x$ while HSLC performances of the districts are considered as $y$ (Eq. 3.2a).

3.1.7 The formation of fuzzy sets in the present content

On analyzing the results of both the tests the performance limits have been independently fixed for SLMO and HSLCE. The graphical representations of the
corresponding fuzzy sets for SLMO and HSLCE are represented in Fig. 4.1 and Fig. 4.2, respectively.

The minimum value was considered as the maximum x value having zero truth-value for SLMO. Similarly, the minimum value was considered as the maximum y value having zero truth-value for HSCLC. These limits are set as the minimum expectation level of performance. On the other hand, minimum values having one as truth-value were the maximum SLMO for SLMO (x) and maximum HSLCE pass percentage for HSLCE (y), respectively.

3.1.8 Estimation of Truth values for the selected propositions

For each district, the fuzzy propositions $P_{x, y}$ are estimated as given below.

The value of $A(x)$ characterizes the degree of compatibility of $x$ with the concept of satisfactory performance. The value of $B(y)$ characterizes the degree of compatibility of the high performance of $y$. Finally, the degree of truth, $T(P_{x, y})$ of proposition $P_{x, y}$ is determined by applying the Lukasiewicz implication for the values of $A(x)$ and $B(y)$ using the following relationship:

$$T(P_{x, y}) = \min [1, 1 - A(x) + B(y)] \quad \text{................. (3.3)}$$

3.1.9 Test for statistical significance

The dependency of HSLCE and SLMO results has also been examined through statistical procedure using both PEARSON’S co-relation and SPEARMAN’S
rank co-relation co-efficient. The average HSLCE pass percentage would be taken as indicator of mathematics performance if the estimates were found positive with high degree of significance.

The districts were then divided into two strata based on HSLCE pass percentage. The first stratum comprises the districts with pass percentage more than forty while the second one comprises the district with pass percentage forty or below. Then using stratified two stages random sampling method the first stratum was selected at random out of which the district was selected at random.


3.2 Selection of Schools

List of schools with SEBA curriculum of the selected District was collected from the official record of Education Department, Govt. of Assam. The prevailing classification criteria of schools are based on the financial and managerial assistance of the Government or private initiative. According to such criteria the schools are categorized into five distinct groups: (i) Government (GO: fully managed by Government), (ii) Provincialized (PZ: Partially managed by Government), (iii) Recognized (RG: Government has recognized for provincialization, but has not come under government management/assistance), (iv) Non-recognized (NR: established by private effort and only with permission of Government) (v) Private (PR: established and run by private party).
Again, location of the schools is also considered as one of the criteria for grouping. Accordingly schools are classified into urban (U) and rural (R).

Schools are selected to have representation in each category mentioned above based on a standard randomized procedure (Epi-info sample size).

Selected schools are coded for convenience of their meaningful identification with reference to category and age. After finalizing the study schools, 25% of the total pupil of class X of each school is selected for evaluation and performance analysis.

3.3 Collection of information from selected Schools

Following information is collected from each of the studied schools.

**Basic information:** Year of establishment, number of teachers, total number students, mathematics teachers, basic infrastructure including library, playground etc. were collected using standard pro-forma (Pro-forma I provided in Appendix 3.1).

**HSLCE results:** In addition to overall pass percentage, the percentage of pass in mathematics, numbers of first division, second division obtained in each of the selected schools were collected. This information was collected pertaining to three consecutive years ending 2006. (Pro-forma I provided in Appendix 3.1).

**Class test results:** Annual examination results of two previous classes (VIII and IX) of all the selected students were collected. The overall percentage and percentage of marks obtained in mathematics were also collected in respect of the selected students.
Teachers' information: Pro-forma II is designed to collect information and responses from mathematics teachers of the selected schools (comfort level of teaching, training need, observations on students & guardian, text book, syllabus, work load, infrastructure, academic environment etc., Pro-forma II is provided in Appendix 3.2)

Students' information: Pro-forma III is designed to collect information and responses from selected students (comfort level of mathematics learning, parents & teachers involvement, support obtained, and perception, Pro-forma III is provided in Appendix 3.3)

Parents' information: Pro-forma IV is designed to collect information and responses from the parents of selected students (observation on students, teachers and schools, awareness about students' performance and financial status. Pro-forma IV is provided in Appendix 3.4)

The relevant information as per the Pro-forma I-IV was collected by personal visit to all the selected schools. Besides, syllabus and textbooks used by the study groups were also collected.

3.4 Assessment of performance based on HSLCE and annual Examination Results

As mentioned earlier, High School Leaving Certificate Examination (HSLCE) is a common test for 10th standard students conducted by The Board of Secondary Education, Assam (India) under the state Government of Assam. There
are altogether six different subjects in the HSLCE including mathematics. In general, a minimum of 30% of the total marks in all subjects is fixed for declaring pass i.e. success in HSLCE. In the present study, HSLCE passing percentages of each school during three consecutive years viz., 2004, 2005 and 2006 are collected as a measure of overall academic performance of the schools.

3.4.1 Comparison of performances through ranking based on HSLCE and Class Examination results

The school conducts annual test of all the six subjects including mathematics. Though each school conducts test individually, the syllabus is common and therefore, the test is considered uniform treatment for all the study school. For the present study, following information relating to results of annual tests for all the students are collected:

(a) percentage scores of all the subjects excluding mathematics and
(b) percentage scores in mathematics subject only.

Three indicators were defined as a measure of academic performance of the schools under study as discussed below.

Pass percentage in HSLCE (PSLCE): The average percentages of successful students in HSLCE during 2004, 2005 and 2006 of a school are used to estimate PSLCE of the school. It is assumed that higher the PSLCE better the academic performance of the school.
**Class average performance excluding mathematics (CAO):** This is the average of the individual students' percentage score in all the subjects excluding mathematics in two consecutive annual examinations viz., Class-VIII and Class-IX. Higher CAO would indicate presence of more number of better students in the school. This is a performance indicator for all subjects except mathematics.

**Class average mathematics performance (CAM):** This is the average of the individual students' percentage score of two consecutive annual examinations (Class VIII and Class IX) in mathematics subject only. Better performance in mathematics would be reflected by higher CAM of a school.

For estimation of CAO and CAM, average percentage score of annual examination results for classes VIII and IX have been used. It is to be noted that CAO reflects the students' ability and school's performance in subjects other than mathematics, whereas, CAM would reflect the students' ability and school's performance in mathematics.

The student: teacher ratio of a school influences academic environment. The ratio of student and teacher (S:T) of all the schools under consideration have been estimated form the collected data of (a) total number of enrolled students and (b) total number of teachers. As the focus of present investigation is on performance in mathematics subject, the ratio of students and mathematics teachers (S:M) has also been estimated and used as an indicator of the academic environment of the school.

The schools are ranked based on (a) PSLCE, (b) CAO, (c) CAM, (d) (S:T) and (e) (S:MT) values. The school with the highest PSLCE is ranked 1, while the
school with the lowest PSLCE is given the lowest rank. All other schools with intermediate PSLCE values are also ranked accordingly. Similar pattern of ranking is used for CAO and CAM, while reverse order is followed for ranking the school for (S:T) and (S:MT). This is due to the fact that lower the S:T or S:MT, better the academic environment of the school.

The CAM ranks are considered as the performance indicator in mathematics subject of the schools. Ranks for other parameters are compared with the CAM ranks through x-y plot to investigate their relationship (CAM ranks are plotted in y-axis, while ranks for other parameters are plotted in x-axis). For a given pair of ranks, greater deviation of the plots from the $x = y$ line would reflect lack of mutual dependence of the parameters.

3.4.2 Application of Fuzzy Logic Propositions to investigate reflection of performance in mathematics subject on other subjects using PSLCE

Mathematics is one of the subjects of HSLCE. The pass percentages of the schools in mathematics subject in HSLCE were also collected for the years under references as mathematics performances in HSLCE. The present investigation aims to analyze the mathematics subject vis-à-vis learners’ performance in the subject. Learners’ behaviour in other subjects has also been a relevant area of the preset investigation. The mutual reflections of performances in mathematics and other subjects using HSLCE results (pass percentages) were investigated using Fuzzy Logic propositions as discussed below.
The basic fuzzy propositions are stated below:

\( P_1: \) There are about \( n \) number of schools in \( I \) whose overall performance \( ov(i) \) is high

\( P_2: \) There are about \( n \) number of schools in \( I \) whose overall performance \( mv(i) \) is high

Where \( I \) is the set of schools considered in the study; \( ov(i) \) is the overall pass percentage of \( i^{th} \) school in \( I \). \( mv(i) \) is the pass percentage in mathematics of \( i^{th} \) school in \( I \). The truth-values will be determined using the average results of three consecutive years as mentioned above with some assumed \( n \). The estimated truth-values corresponding to the above propositions were compared to investigate the reflection.

3.4.3 Fuzzy logic proposition with fuzzy quantifiers

In our present study we have used a fuzzy logic proposition with fuzzy quantifiers to investigate the reflection of mathematics performance on academic sceneries of secondary schools. In fuzzy logic, fuzzy quantifiers are fuzzy numbers that take part in fuzzy propositions. A wide variety of fuzzy quantifiers are classified in to two different types. Fuzzy quantifiers of the first type are defined on \( R \) and characterize the linguistic terms such as about 2, much more than 4, at least about 6 and so on. Fuzzy quantifiers of the second type are defined
on \([0, 1]\) and characterize linguistic terms such as most, almost always, frequently, about half and so on. In our study we have used the fuzzy proposition that contain the fuzzy quantifier of the first kind. The proposition of such form that we have used is:

\[
P : \text{There are } Q \text{ 's in } I \text{ such that } v(i) \text{ is } F, \quad (3.4)
\]

Where \(v\) is a variable that for each individual \(i\) in a given set \(I\) assumes a value \(v(i)\), \(F\) is a fuzzy set defined on the set of values of variable \(v\), and \(Q\) is a fuzzy number on \(R\). In general, \(I\) is an index set by which distinct measurements of variable \(v\) are distinguished. Any proposition \(P\) of the from (3.4) can be converted into another proposition, \(P_1\), of a simplified form,

\[
P_1 : \text{There are } Q \text{ 's, } \quad (3.5)
\]

Where \(Q\) is the same quantifier as in (3.4) and \(E\) is a fuzzy set on a given set \(I\) that is defined by the composition

\[
E(i) = F(v(i)) \quad (3.6)
\]

For all \(i \in I\)

Proposition \(P_1\) of the form (3.5) may be viewed as a simplified expressions of proposition \(P\) of the form (3.4). It is common in natural language to use the simplified form in lieu of the full form. For the sake of simplicity, the proposition \(P_1\) of the form (3.5) may be rewritten in the form

\[
P_1 : W \text{ is } Q \quad (3.7)
\]

Where \(W\) is a variable taking value in \(R\) that represents the scalar cardinality (sigma out) of fuzzy set \(E\) (i.e. \(W = |E|\)) obviously,
\[ |E| = \sum E(i) = \sum F(v(i)) \]

and for each given fuzzy set \(E\), we have

\[ T(P) = T(P_i) = Q(|E|). \]

Now any given proposition "\(W\) is \(Q\)" induces a possibility distribution function, \(r_Q\), that is defined for each \(E \in \mathbb{R}\) by the equation

\[ r_Q(|E|) = Q(|E|). \]

This possibility distribution acts as an elastic constrained on values of variable \(W\); that is \(r_Q(|E|)\) expresses the degree of possibility that \(W = |E|\).

[G.Klir, Ute. St. Clair, Y. Bo. (1997)]

3.5 Assessment of performance based on specially designed test on Mathematics \textit{i.e.} Mathematical Ability Test (MAT)

A question paper on mathematics was designed for testing mathematics ability of the selected students. The specially designed question paper has the capacity to judge students' performance in different topic besides testing comprehensive ability. The test of each of the selected students is conducted under direct physical supervision of the investigator. The MAT question paper has been provided in Appendix 3.5 and detail of procedure of setting up of MAT question paper is given below.
3.5.1 The procedure and structure of MAT question paper

The MAT question paper had the ability to test the performance in the areas of (i) number sense; (ii) idea of set; (iii) square formula, cubic formulae and their application; (iv) HCF and LCM; (v) algebraic fraction; (vi) variation; (vii) linear simultaneous and quadratic equation; (viii) graph; (ix) ratio and proportion; (x) statistics; (xi) trigonometry; (xii) geometry and (xiii) interest and discount.

Strength and weaknesses of the schools in each of the above mentioned areas were analyzed based on the MAT results.

3.5.2 Testing learner's consistency in performances in mathematics during three consecutive years

As mentioned earlier, MAT was taken for the current class X students who would appear HSLCE. The marks obtained by this group of students in mathematics subject pertaining to class VIII and IX along with the MAT score were used as the performance of mathematics in three consecutive years. Thus, the consistency of individual students in mathematics subject during the last three years could be tested by these three tests in mathematics. For examining the consistency, it was assumed that each individual learner was subjected to identical treatments in the three consecutive years and their ability in the relevant areas of mathematics (which were taught in the classes) was tested. Four levels of consistency as shown in the Table 3.1 were defined to test the consistency of the
individual student. Further, the percentage of learners in each level of consistency in each school was determined.

Table 3.1

**Defining level of consistency**

<table>
<thead>
<tr>
<th>Level of consistency</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistent improvement</td>
<td>MAT &gt; Math(IX) &gt; Math(VIII)</td>
</tr>
<tr>
<td>No consistency, deteriorating</td>
<td>MAT &lt; Math(IX) &gt; Math(VIII)</td>
</tr>
<tr>
<td>No consistency, improving</td>
<td>MAT &gt; Math(IX) &lt; Math(VIII)</td>
</tr>
<tr>
<td>Deteriorating</td>
<td>MAT &lt; Math(IX) &lt; Math(VIII)</td>
</tr>
</tbody>
</table>

3.5.3 **Use of average MAT score as mathematics performance indicator of schools**

As mentioned earlier care was taken to design and conduct MAT under the direct supervision of the investigator for all the selected group of learners belonging to the different schools. The selected group of students was considered as representative of their respective schools. The average MAT score of a group of learners belonging to a particular school was considered the measure of mathematics performance of that school. Thus, mathematics performance of a school was estimated using the following relationship:
\[ MP = MAT_{av} \quad \ldots \ldots (3.8) \]

Where, \( MAT_{av} \) is the average \( MAT \) scores of the group of learners belonging to a school and \( MP \) is the measure of performance in mathematics of that school. Average is only one indicator of performance of a group.

3.5.4 Use of MAT results to rank the selected school through uniformity of performances

Besides average value, some other parameters such as maximum, minimum and standard deviation are also meaningful. A group with higher maximum, higher minimum, higher average and lower standard deviation of the score is desirable. Such a group would mean presence of better performer students with more uniformity of performance. The basic statistics of the MAT results of the schools were used to estimate a parameter as given below:

\[ UMPI = \frac{MAT_{\max} \times MAT_{\min} \times MAT_{av}}{MAT_{sd}} \quad \ldots \ldots (3.9) \]

Where, \( MAT_{\max} \) is the maximum mark, \( MAT_{\min} \) is the minimum mark scored in a group and; \( MAT_{sd} \) is standard deviation of the scores of the group and \( UMPI \) is the uniformity mathematics performance index of the school.

Overall, the MAT score along with the class test score in mathematics subject of the students have three distinct uses viz., (i) assessment of strength and weaknesses of the schools in selected sub-areas of mathematics; (ii) assessment of consistency of performance of students; (iii) as indicators of mathematics
performance of school and (iv) ranking of school based on UMPI. In addition to these, differentiated MAT scores would also be used to analyze the syllabus.

3.6 Analysis of course curriculum on the background of MAT performance

As discussed earlier, the MAT question paper was prepared to test the performance in the areas of (i) number sense; (ii) idea of set; (iii) square formula, cubic formulae and their application; (iv) HCF and LCM; (v) algebraic fraction; (vi) variation; (vii) linear simultaneous and quadratic equation; (viii) graph; (ix) ratio and proportion; (x) statistics; (xi) trigonometry; (xii) geometry and (xiii) interest and discount.

The learners' performances in each of the specified areas were averaged for each of the schools based on the MAT results. Performances in each of the areas were considered for examining the mathematics syllabus followed.

3.7 Design and assessment of Educational Environment (EE)

Varying degree of mathematics performances of the schools under study was anticipated. One of the objectives of the present investigation was to measure such variable performances of the schools. However, investigation of the causes of
such varying degree of performances seemed to be more useful for improving mathematics education. Need of standard methodology was realized for investigating the cause and effect relationship. Several social, economic, academic as well as technical factors influence mathematics performance considered for the present study. There have been many procedures available for studying such multifaceted social issues. However, it is felt that the present investigation would require special treatment and specific procedure. Therefore, it is attempted to design a parameter named Educational Environment (EE) which could comprehensively consider all the relevant factors influencing the performance of a learner. The design of EE involves (i) conceptualization of the situation exposed to the learners; (ii) delineation of the situation into boarder groups; (iii) further division of the delineated groups into measurable factors and (iv) assigning proportionate values to the factors. Finally, EE is estimated based on assumed functional relationship. The detail procedure is discussed below:

3.7.1 Delineation of the academic situation into boarder groups

Based on the experiences and earlier works, three characteristic factors (groups) are identified which influence the academic performance. Using these three characteristics educational environment (EE) is defined with a functional relationship as given below:

\[ EE = f(SC, TC, DS) \]  \hspace{1cm} (3.10)

Where, \( SC \) is the school characteristics; \( TC \) is the teacher characteristic and \( DS \) is the learner's domestic status.
3.7.2 Division of the delineated groups into measurable factors

Again, the parameters embedded in the functions (Eq.3.10) are expected to be influenced by some other factors. All the probable factors prevailing in the study area are identified. Thus, the parameters are further, defined using the relationship given below:

\[ SC = f_1(I, M, ST, AA, PI) \] \hspace{1cm} \ldots (3.10a)

\[ TC = f_2(TQ, TT, TW, TM, PS) \] \hspace{1cm} \ldots (3.10b) \text{ and }

\[ DS(i) = f_3(FC, PE, PA, M, F) \] \hspace{1cm} \ldots (3.10c)

Where, the symbols in the right hand side of Eq. 3.10a to 3.10c represent factors such as, \( I \): infrastructure, \( M \): management, \( ST \): student teacher ratio, \( AA \): academic activities, \( PI \) parents involvement, \( TQ \): level of teacher qualification, \( TT \): level of teacher training, \( TW \): work load of teacher, \( TM \): teaching methods, \( PS \): perception on the subject, \( FC \): financial condition, \( PE \): parents educational background, \( PA \): parents awareness, \( M \): motivation, and \( F \): facilities.

Thus, EE is described by 15 distinct factors in three groups. Questionnaires were prepared (Appendices 3.1 to 3.4) to record the precisely the status of these 15 factors. Some of the factors required more than one question to their status.

3.7.3 Assigning proportionate values to the factors

Some of the factors mentioned in Eq. 3.5a, 3.5b and 3.5c could be quantitatively measured, whereas some others could be assessed qualitatively.
Standard method was used to convert the recorded information (both quantitative and qualitative) into representative score values of each of the factors. The criteria of assigning scores are provided in Table 3.2 to Table 3.4. SM indicates student: mathematics teacher ratio

The sum total of the individual score values pertaining to the measured/recorded factors of given schools were estimated to obtain the values of SC and TC of the schools under study. Similarly, DS(i) was estimated totaling the scores of recorded factors concerning the i\textsuperscript{th} student of a given school. DS(i) of the student of a given school was averaged to obtain the DS of the school. Finally SC, TC and DS were added to obtain EE of a school.

### 3.8 Investigation of the effect of EE on mathematics performance

Investigations of the effect of educational environment (EE) on mathematics performance (MP) of the schools under study were also made. The significance of the effect of EE on MP was tested through appropriate statistical procedure (Hypothesis testing) and Fuzzy logic applications as discussed below.
### Table 3.2

**Scoring pattern for school characteristics (SC) and description of attributes**

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Description of facility etc</th>
<th>1.00</th>
<th>0.75</th>
<th>0.50</th>
<th>0.25</th>
<th>0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infrastructure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School Building</td>
<td>very good</td>
<td>good</td>
<td></td>
<td></td>
<td>bad</td>
<td>very bad</td>
</tr>
<tr>
<td>Library</td>
<td>adequate</td>
<td>exists, partially satisfactory</td>
<td></td>
<td>exists, limited books</td>
<td>Exists, very limited books</td>
<td>Does not exist</td>
</tr>
<tr>
<td>Electricity</td>
<td>fully connected</td>
<td>partially connected (few remains out of connection)</td>
<td></td>
<td>limited connection (few remains connected)</td>
<td>only office is connected</td>
<td>No connection</td>
</tr>
<tr>
<td>Play ground</td>
<td>very good</td>
<td>good</td>
<td></td>
<td></td>
<td>bad</td>
<td>very bad</td>
</tr>
<tr>
<td><strong>Management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class room</td>
<td>Very well managed</td>
<td>Well managed</td>
<td></td>
<td>Managed</td>
<td>Poorly managed</td>
<td>Not cared</td>
</tr>
<tr>
<td>Out of class room within the school</td>
<td>Very well managed</td>
<td>well Managed</td>
<td></td>
<td>Managed</td>
<td>Poorly managed</td>
<td>Not cared</td>
</tr>
<tr>
<td><strong>Student-teacher ratio</strong></td>
<td>within 5th rank</td>
<td>6th to 10th rank</td>
<td>11th to 15th rank</td>
<td>higher than 16th rank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(relative score based on existing ratios which are ranked in increasing order)</td>
<td>within 5th rank</td>
<td>6th to 10th rank</td>
<td>11th to 15th rank</td>
<td>higher than 16th rank, less than 500 SM</td>
<td>more than 500 SM</td>
<td></td>
</tr>
<tr>
<td><strong>Academic activities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic meetings</td>
<td>Frequent &amp; meaningful</td>
<td>Less frequent &amp; satisfactory participation</td>
<td>Less frequent</td>
<td>Not Frequent</td>
<td>No meeting</td>
<td></td>
</tr>
<tr>
<td>Interaction with other academic institution</td>
<td>Frequent &amp; meaningful</td>
<td>Less frequent &amp; satisfactory participation</td>
<td>Less frequent</td>
<td>Very rare</td>
<td>No interaction</td>
<td></td>
</tr>
<tr>
<td><strong>Arrangement of parents involvement by school</strong></td>
<td>Regular &amp; meaningful parents meetings</td>
<td>Less frequent &amp; satisfactory</td>
<td>Less frequent</td>
<td>Very rare</td>
<td>No involvement</td>
<td></td>
</tr>
</tbody>
</table>
### Table 3.3

**Scoring pattern for teacher characteristics and description of attributes**

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Maximum scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Qualification</td>
<td></td>
</tr>
<tr>
<td>Under graduate</td>
<td>No training</td>
</tr>
<tr>
<td>Bachelor degree</td>
<td></td>
</tr>
<tr>
<td>Related training more than 7 days</td>
<td></td>
</tr>
<tr>
<td>Master degree</td>
<td></td>
</tr>
<tr>
<td>Related training more than 30 days</td>
<td></td>
</tr>
<tr>
<td>No training</td>
<td></td>
</tr>
<tr>
<td>Bachelor degree with B. Ed. degree</td>
<td>Master degree</td>
</tr>
<tr>
<td>Related training more than 90 days</td>
<td></td>
</tr>
<tr>
<td>Related training more than 60 days</td>
<td></td>
</tr>
<tr>
<td>Related training more than 30 days</td>
<td></td>
</tr>
<tr>
<td>Flexible, not sensitive to any one, no feedback assessed</td>
<td></td>
</tr>
<tr>
<td>Flexible as per the need of all section of learners, regular feedback assessed</td>
<td></td>
</tr>
<tr>
<td>Flexible as per the need of all section of learners</td>
<td></td>
</tr>
<tr>
<td>Flexible, not sensitive to insensitive to any one, no feedback evaluated</td>
<td></td>
</tr>
<tr>
<td>Monotonous teaching</td>
<td></td>
</tr>
<tr>
<td>Work load</td>
<td></td>
</tr>
<tr>
<td>SM up to 40</td>
<td>SM: 41 to 80</td>
</tr>
<tr>
<td>Teaching method</td>
<td></td>
</tr>
<tr>
<td>Flexible as per the need of all section of learners, regular feedback assessed</td>
<td></td>
</tr>
<tr>
<td>Flexible as per the need of all section of learners</td>
<td></td>
</tr>
<tr>
<td>Flexible, not sensitive to insensitive to any one, no feedback evaluated</td>
<td></td>
</tr>
<tr>
<td>Monotonous teaching</td>
<td></td>
</tr>
<tr>
<td>Perception leading to effective teaching</td>
<td>Most effective teaching</td>
</tr>
</tbody>
</table>

SM: Student Motivation
<table>
<thead>
<tr>
<th>Attributes</th>
<th>Maximum score</th>
<th>Financial condition, based on monthly income</th>
<th>Parents educational background</th>
<th>Parents awareness</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>more than Rs. 16000</td>
<td>Above 12th standard below graduation</td>
<td>None of (a), (b), (c)</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rs. 11000 to Rs. 16000</td>
<td>Above 12th above 10th</td>
<td>Any one of (a), (b)</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rs. 6000 to Rs. 11000</td>
<td>Below 12th above 10th</td>
<td>Any one of (a), (b)</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>less than Rs. 6000</td>
<td>Below 8th</td>
<td>None of (a), (b), (c)</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>less than Rs. 1000</td>
<td>Below 8th</td>
<td>None of (a), (b), (c)</td>
<td>0.00</td>
</tr>
</tbody>
</table>

- (a) Parents teacher meeting attended;
- (b) Meeting teacher to discuss academic progress of students;
- (c) Parents aware of academic progress of students.
<table>
<thead>
<tr>
<th>Provision for addressing academic difficulties through additional facility</th>
<th>Very particular in fulfilling all academic needs of learner</th>
<th>Fulfills academic needs of learner as per the convenience</th>
<th>Fulfills academic needs of learner on the basis of priority</th>
<th>Fulfills academic needs of learner rarely</th>
<th>Cannot fulfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parents action to motivate learners</td>
<td>Regularly keeping in touch and positive encouragement</td>
<td>Attending learner when asked for and positive encouragement</td>
<td>Attending learner when asked for; encouraging sometimes</td>
<td>Attending learner when asked for</td>
<td>In different, No positive encouragement</td>
</tr>
<tr>
<td>(c) Regular interaction with learner to learn status of learning at schools</td>
<td>regularly and</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.8.1 Hypothesis testing through application of statistics

Three Hypotheses were postulated to investigate the effect of components of \( EE \) on \( MP \) as given below:

Hypothesis 1: Learner’s performance \( (MP) \) is not affected by school characteristic \( (SC) \)

Hypothesis 2: Learner’s performance \( (MP) \) is not affected by teacher characteristic \( (TC) \)

Hypothesis 3: Learner’s performance \( (MP) \) is not affected by domestic status \( (DS) \)

Further, one more hypothesis was postulated to investigate the effect of \( EE \) on \( MP \) as given below:

Hypothesis 4: Learner’s performance \( (MP) \) is not affected by educational environment \( (EE) \)

For testing all the above-mentioned hypotheses, Karl Pearson coefficient of correlation was used as given below:

\[
r(x, y) = \frac{\text{cov}(x, y)}{\sqrt{\text{var}(x) \cdot \text{var}(y)}}
\]

\[\ldots \ldots (3.11)\]

Where \((x_i, y_i), i=1,2,\ldots, N\) is a bivariate data pertaining to parameter \( x \) and \( y \).

The value of correlation coefficient \( r(x, y) \) varies from \(-1\) (perfect negative relationship) through \(0\) (no relationship) to \(+1\) (perfect positive relationship). If the value of correlation coefficient fall at intermediate points, such as \(0.78, -0.28, 0.65\) etc. then correlation will be “high” or “low” depending upon how close they are to
±1.00. If the value of correlation coefficient is zero then hypothesis is accepted. On the other hand if the value is different from zero then hypothesis is rejected.


3.8.2 Application of Fuzzy Logic propositions to investigate the effect of EE and its components on MP

Fuzzy Logic propositions were postulated to investigate the effect of (i) SC, (ii) TC and (iii) DS on MP. Further, the proposition was also used to investigate the effect of EE on MP. The proposition is discussed below.

The conditional and unqualified fuzzy logic proposition of the following type was used:

\[ P: \text{If } X \text{ is } A \text{ then } Y \text{ is } B \quad \ldots \ldots (3.12) \]

Where, \( x \) and \( y \) are variables whose values are in sets \( X \) and \( Y \), respectively. \( A \) and \( B \) are relevant predicates represented by fuzzy sets.

If ' \( X \) is \( A \)' and ' \( Y \) is \( B \)' are represented as \( A(x) \) and \( B(y) \), respectively, then the proposition (3.12) is written as

\[ P_{xy}: \text{If } A(x), \text{ then } B(y) \quad \ldots \ldots (3.12a) \]

The propositions formulated are:

Proposition 1: \( P_1 \): If school characteristic (SC) is satisfactory then mathematics performance (MP) is high.

Proposition 2: \( P_2 \): If teacher characteristic (TC) is satisfactory then mathematics performance (MP) is high.
Proposition 3: P₃: If learners' domestic status (DS) is satisfactory then mathematics performance (MP) is high.

Proposition 4: P₄: If educational environment (EE) is satisfactory then mathematics performance (MP) is high.

For the proposition 1, the concept "school characteristic is satisfactory" and "mathematics performance is high" are expressed by fuzzy sets A and B, respectively. Where, school characteristic score (SC) of schools is considered as \( X \) while mathematics performance score (MP) of schools is considered, as \( Y \). Similar conception would be applicable for the remaining three propositions.

3.9 Comprehensive analysis and recommendation

Recommendations will be formulated based on the critical analysis and investigation specific to (i) components of academic environment and (ii) mathematics syllabus and textbooks with an aim for effective improvement in secondary level mathematics in Assam.