CHAPTER III

METHOD

3.0 Introduction

Educational research is a type of systematic investigation that applies empirical methods to solve challenges in education. It adopts rigorous and well-defined scientific processes to gather and analyze data for problem-solving and knowledge advancement.

The methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge.

The method of the present study has two stages.

Stage 1: Design and Development of Computer Assisted Cartesian Plane

Stage 2: Study the Effectiveness of Computer Assisted Cartesian Plane

Computer Assisted Cartesian Plane was developed to support students with visual impairment in executing *Plotting* and *Finding Points* on the Cartesian plane independently which they have been deprived of the existing educational settings.

To study the effectiveness of the Computer Assisted Cartesian Plane, the students with visual impairment who are the end-user were selected to execute *Plotting* and *Finding Points* using Computer Assisted Cartesian Plane.

To substantiate the effectiveness of the Computer Assisted Cartesian Plane system, the Special Teachers and Student Teachers were involved to provide their rating about the system.

3.1 Stage I: Design and Development of Computer Assisted Cartesian Plane

Computer Assisted Cartesian Plane has been developed using the language called Visual Basic. The “Visual” part refers to the method used to create the graphical user interface (GUI). The “Basic” part refers to the BASIC (Beginners All-Purpose Symbolic Instruction Code) language, a language used by more programmers than any other language in the history of computing. Development of Computer Assisted

Cartesian Plane required both Hardware and Software. The hardware requirements are Intel DUAL CORE Processor, 2 GB SD RAM (DDR2) Memory, and 750 GB HDD Disk drives. The software requirements are Windows XP or a higher version of windows and Microsoft Visual Studio 6.0.

a. Life Cycle of Computer Assisted Cartesian Plane Development

System development life cycle is the process of designing, implementing, and testing the system to remove bugs, defects, and uncertainty in the system and achieve reliability.

The life cycle of Computer Assisted Cartesian Plane development explains developing the software system for students with visual impairment. The life cycle process deals with six phases. They are listed below.

1. Planning Phase

This phase describes the planning of requirements of the entire Computer Assisted Cartesian Plane development. Initially, the development team discussed with the stakeholders to figure out the requirements of the stakeholders and end-user. It involves

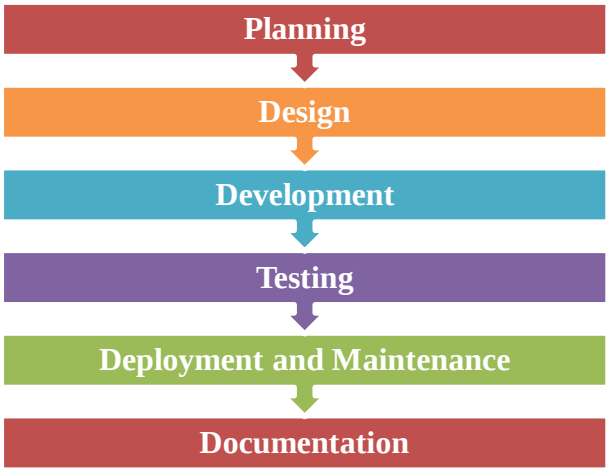


Fig 3.1 : The Life Cycle of Computer Assisted Cartesian Plane Development

- The objective of designing Computer Assisted Cartesian Plane
- User requirements
- An official and non-official requirement which includes Stationery items
- Manpower involved
- Time taken to complete the Computer Assisted Cartesian Plane
- Budget for developing Computer Assisted Cartesian Plane
- Possible Occurrence of Errors while developing Computer Assisted Cartesian Plane

- Required Software for implementation.

The above-mentioned key points were analysed and documented. Based on the planning, the rest of the phases was developed. More time had been taken for the planning phase, as the entire software development depended on the planning phase. The time taken for this planning phase was one month.

2. Designing Phase

In this phase, a prototype of the Computer Assisted Cartesian Plane tool or blueprint of Computer Assisted Cartesian Plane was designed. This showed what the end product looks like. This phase involved the designing of Pseudocode and algorithm, Flow chart, Input and Output window, Blueprint, Module, Variables analysis, Class/Object diagram were developed. The time taken for this designing phase was one month.

3. Development Phase

In this phase, the Computer Assisted Cartesian Plane software was developed. The development team overviewed the design performed in the designing phase. Through this, each module had been developed individually. The software used to implement Computer Assisted Cartesian Plane is Visual Basic 6.0. The Development of the software system took two months time duration.

4. Testing Phase

This testing phase is necessary to free from bugs and errors. The software has to work in all situations without any errors. Integrated testing was performed for the entire system to check for errors. In the occurrence of the error, the identified error was corrected and again testing was performed. The process was repeated until the developed Computer Assisted Cartesian Plane system had become error-free. This phase consumed a one-month time duration.

5. Deployment and Maintenance Phase

Once the Computer Assisted Cartesian Plane system was developed, the developed system was open to the students with visual impairment for usage. Feedback was gotten from the students regarding their ease of use, difficulties, and

future enhancement. Based on that, the tool was modified. Since it was an iterative process it took two months for iteration which included testing.

6. Documentation Phase

Documentation here means documenting the entire Computer Assisted Cartesian Plane tool in text and images.

The following Gantt chart in the table explains the time taken for each phase to implement. The total duration of the development process was eight months.

Table 3.1: Gantt Chart for Software Development

Phases vs. Duration in Months	1	2	3	4	5	6	7	8
Planning								
Design								
Development								
Testing								
Deployment & maintenance								
Documentation								

b. Module description of Computer Assisted Cartesian Plane

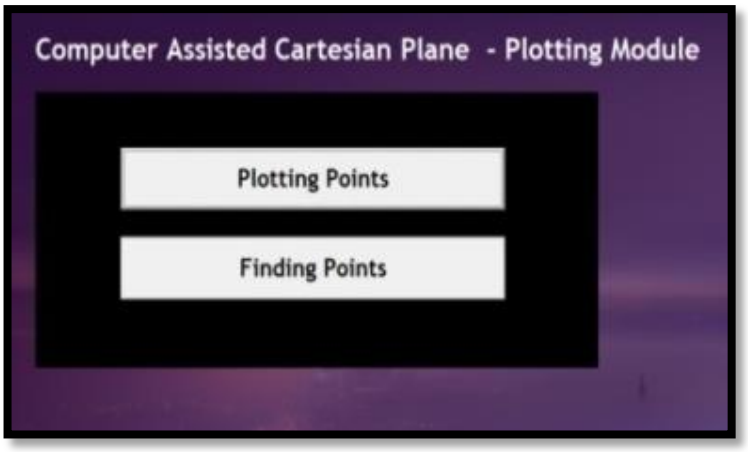


Fig 3.2 : Screenshot of Main Screen

The entire software is divided into two modules namely *Plotting Points* and *Finding Points*.

Further, each of these modules has three modes namely Learning, Practice, and Evaluation. The modules have been developed individually and clubbed together finally to make the software as a single unit.

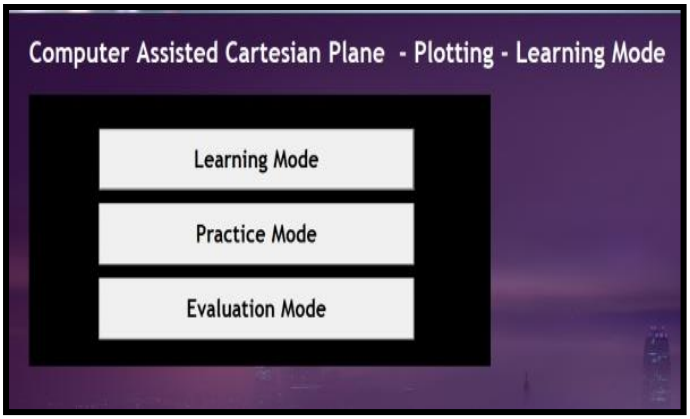


Fig 3.3: Screenshot of Plotting Points Module : 3 Modes

1. Execution Window

The below screenshot diagram presents the details in the Execution Window. For all the modules, the execution window is split into two columns. On the left side, the working area of the graph is portioned. On the other side, instructions are displayed. There is a drop-down box available on the right side either to select the readily available coordinates or the user can give the input.

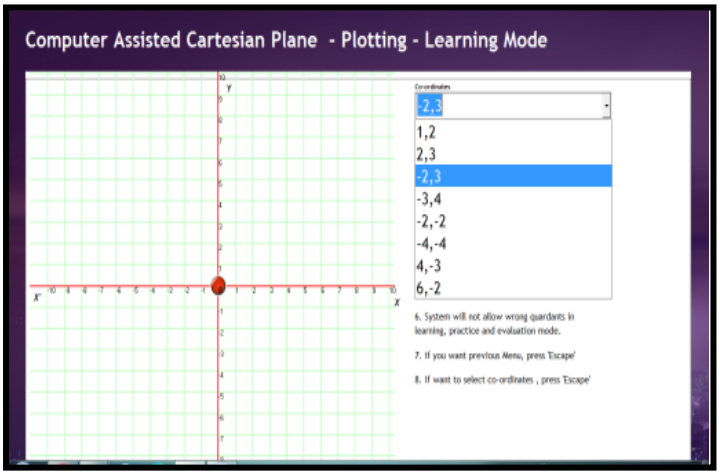
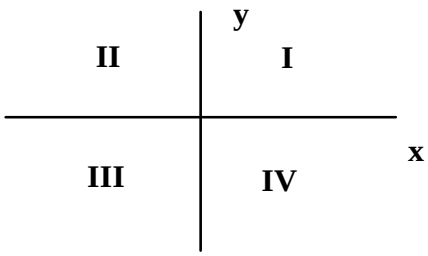


Fig 3.4 : Screenshot of Execution Window

Once the coordinates are selected or given, the software analyzed the quadrant and fixes the point internally based on the values of x-coordinate and y-coordinate. This helps the avoidance of movement beyond the coordinate points done by the students with visual impairment.

The figure shows the quadrant number allocation based on x-coordinate and y-coordinate.



1. In I Quadrant, both the x– and y-coordinates are positive
2. In II Quadrant, the x-coordinate is negative, but the y-coordinate is positive
3. In III Quadrant, both the x– and y-coordinates are negative
4. In IV Quadrant, the x-coordinate is positive, but the y-coordinate is negative.

Whenever a coordinate is given, the software analyses and fixes the quadrant as it is predetermined. Initially, the pointer points to the coordinates of the origin (0, 0).

2. Keys Used

Limited numbers of keys were used to operate the Computer Assisted Cartesian Plane. The following are the keys selected for the entire operation of the Computer Assisted Cartesian Plane.

Table 3.2: Keys used to operate Computer Assisted Cartesian Plane

S.No	Keys Used		Operation
1.	Shift		For selection. Similar to ENTER key option
2.	Esc		Go back to the Previous Page
3.	Up arrow		Moving towards Positive values on the y-axis
4.	Down arrow		Moving towards negative values on the y-axis
5.	Right arrow		Moving towards positive values on the x-axis
6.	Left arrow		Moving towards negative values on the x-axis
7.	Number Key		To type the coordinates
8.	Comma key		To separate the coordinates

Other than these, the common keys such as Delete key and Backspace key to delete when it is wrongly typed and to adjust the space were used.

3. Identification of Quadrant using Numeric Keys in Finding Points Module

The below table shows the combination of key movements after the quadrant is fixed by the software. This helps the student with visual impairment to restrict the wrong movement of the keys. Prior knowledge regarding the key movements was given to the students with visual impairment before the start of the session.

Table 3.3: Combination of keys based on Quadrant Number

S.No	Quadrant number	x-axis	y-axis
1	I	Right Arrow key 	Up Arrow key 
2	II	Left Arrow key 	Up Arrow key 
3	III	Left Arrow key 	Down Arrow key 
4	IV	Right Arrow key 	Down Arrow key 

Table 3.4: Identification of Quadrant using Numeric keys in Finding Points Module (Additional)

S.No	Numeric key	Quadrant number
1	1	I
2	2	II
3	3	III
4	4	IV

These are the key operations performed by students with visual impairment while using the Computer Assisted Cartesian Plane system.

4. Module 1: Plotting Points

In this module, the student with visual impairment has to plot a given point on the graph. *Plotting Points* has three modes namely Learning, Practice, and Evaluation. Figure 3.5: shows the various modes in Plotting Points.

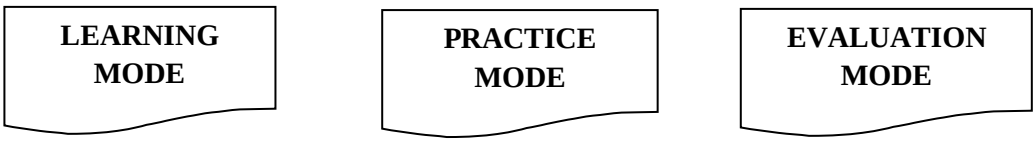


Fig 3.5: Plotting Points: 3 Modes

i. Mode 1: Learning: Working Principle

Initially, the basic steps mentioned above are followed. Selecting or entering the coordinate values would fix the quadrant. This helps to avoid unwanted movement done by students with visual impairment. Once the coordinate values are given, the Computer Assisted Cartesian Plane system informs the quadrant number where the coordinate points, as well as the respective keys, are used to move on the x-axis and y-axis. The student has the pre-knowledge of keys combination for different quadrants. The tool indicates the students with visual impairment with a beep sound when the student moves the pointer in the right direction; otherwise, a voice message will be loud out as "*Wrong, Try Again*". The Computer Assisted Cartesian Plane system uses the voice message "*You have reached the x-coordinate*", once the user reaches the x-coordinate and informs the user when he/she reached the destination point using the voice message "*You have reached the destination point*". While learning, the student with visual impairment encounters errors in moving the keys. So, the system always guides the student in the learning process. It allows an infinite number of errors while learning happens. The following pseudo-code explains the working principle of Learning Mode in *Plotting Points***.**

Pseudo Code for Learning Mode in Plotting Points Module

```
BEGIN
      Wrong Count = 0
      DISPLAY instructions
      IF userMode = "Plotting" THEN
            INPUT coordinates (X_Max & Y_Max)
      END IF
      IF  Xcount  >= X_Max   THEN
                  Play Audio Beep
            ELSE
                  Wrong Count + = 1
      END IF
PLAY AUDIO  "You have reached the X coordinate"
```

```
            IF Ycount >=  Y_Max   THEN
                        PLAY AUDIO Beep
                  ELSE
                        Wrong Count + = 1
            END IF
PLAY AUDIO  "You have reached the destination point"
END
```

ii. Mode 2: Practice: Working Principle

It is similar to the learning module until typing or selecting the question from the dropdown box. Once the coordinates are given, the student with visual impairment has to plot a point on Cartesian Plane remembering the combination of arrow keys. No intimation about quadrants and arrow keys to the student is given. Instead of that, the system command in voice message as "*Find x- coordinate*". Using beep sound, the visually impaired student has to move the pointer in the right direction and receive a voice message as "*You have reached the x-coordinate"*. The command *"Find y-coordinate*" will be sounded for a further move and "*Wrong, Try Again*" will be sounded for every wrong move. When he/she reached the destination point, the Destination reached dialog box appears and receives a voice Message as "*You have reached the destination point*".

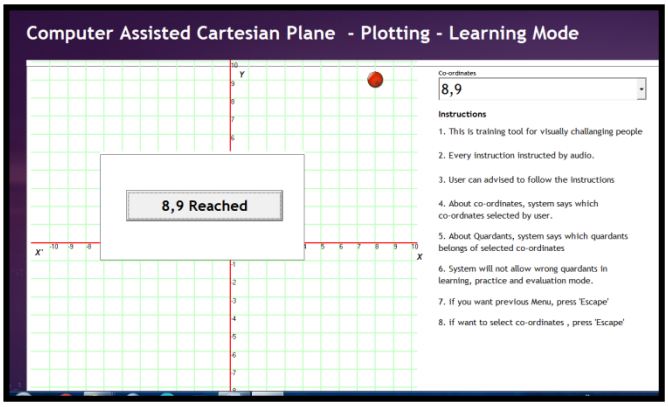


Fig 3.6 : Screenshot of Destination reached

The following pseudo-code explains the working principle of Practice Mode in *Plotting Points*.

Pseudo Code for Practice Mode in Plotting Points Module

```
BEGIN
     Wrong Count = 0
     HIDE instructions
     IF userMode = "Plotting" THEN
          INPUT coordinates (X_Max & Y_Max)
     END IF
     IF  Xcount  >= X_Max   THEN
               PLAY AUDIO Beep
          ELSE
               Wrong Count + = 1
     END IF
PLAY AUDIO "You have reached the X coordinate"
     IF Ycount >=  Y_Max   THEN
               PLAY AUDIO Beep
          ELSE
               Wrong Count + = 1
     END IF
PLAY AUDIO "You have reached the destination point"
END
```

iii. Mode 3: Evaluation: Working Principle

The former two modes are used for learning and practicing. But, the third mode is mainly used for testing or evaluating the students with visual impairment with queries. Here, no information about the quadrant or arrow keys is provided to the students. The coordinate (x, y) would be given by the Instructor / Teacher or by selecting the coordinates from the drop-down box where all possible coordinates are already available. Once the question is set, the student with visual impairment starts moving the pointer using arrow keys. The two main differences between former cases viz Learning mode, Practice mode and later case in Evaluation mode, the student with visual impairment is permitted to do two errors. More than two errors will lead to the current page closure leading to the main menu. Only the voice output is there for commanding/prompting the user/ student to find x- and y- coordinate and for reaching the destination.

The following pseudo-code explains the working principle of Practice Mode in *Plotting Points***.**

Pseudo Code for Evaluation Mode in Plotting Points

```
BEGIN
     Wrong Count = 0
     HIDE instructions
          IF userMode = "Plotting" THEN
          INPUT coordinates (X_Max & Y_Max)
     END IF
     IF  Xcount  >= X_Max   THEN
               PLAY AUDIO Beep
          ELSE IF WrongCount = = 2
                    PLAY AUDIO "Wrong, try again"
                    BREAK
               ELSE
                    Wrong Count + = 1
     END IF
     IF Ycount >=  Y_Max   THEN
          PLAY AUDIO Beep
               ELSE IF WrongCount  = = 2
                         PLAY AUDIO "Wrong, try again"
                         BREAK
                    ELSE
                         Wrong Count + = 1
     END IF
PLAY AUDIO "You have reached the destination point"
END
```

The table depicts the comparison of all the three modes of the *Plotting Points* phase based on its operation.

Table 3.5 Comparison of Learning, Practice, and Evaluation in Plotting Points Module

S.No	Operations	Learning	Practice	Evaluation
1.	Intimation of quadrants	Yes	No	No
2.	Intimation of Keys to reach x- and y-coordinates	Yes	No	No
3.	A beep sound is received for every right movement	Yes	Yes	Yes
4.	Voice message for reaching x-coordinate and y- coordinate	**Best case**: "You have reached the Destination Point" **Worst case**: "Wrong, Try Again"	**Best case**: "You have reached the Destination Point" **Worst case**: "Wrong, Try Again"	**Best case** : "You have reached the Destination Point" **Worst case**: "Wrong, Try Again"
5.	Number of errors allowed	Any	Any	2

5. Module 2: Finding Points

Using the SHIFT key, Finding Points is selected from the main window. The main difference between *Plotting* and *Finding Points* in this system is, in *Plotting Points*, the coordinate (x, y) values are known and the student with visual impairment needs to plot the point on the Cartesian Plane. In *Finding Points*, the coordinate (x. y) values are unknown to students with visual impairment. The Instructor / Teacher will give the coordinate values and the student has to find out the value of x- and y-coordinates using arrow keys.

Similar to the *Plotting Points* module, there are 3 modes in *Finding Points* namely Learning, Practice, and Evaluation as shown in figure 3.2(c). For all three modes, the quadrants are identified by pressing the numeric keys 1, 2, 3, and 4. This is done once the coordinate values are given randomly or selected to the students with visual impairments.

The working Mechanism: Press the numeric key 1 followed by the SHIFT key and if the point lies on the 1st quadrant, a voice message will be sounded to the student with visual impairment as "*Yes, the point lies on 1st Quadrant*" and "*Press the right arrow key to reach x-coordinate and Press the upper arrow key to reach y-coordinate*". If the point does not lie in 1st quadrant then no voice output will be sounded to the student. Through this, the student understands in which quadrant the point lies. After that, the usual procedure gets starts in *Finding Points*.

Fig. 3.7: Finding Points: 3 Modes

i. Mode 1: Learning: Working Plane

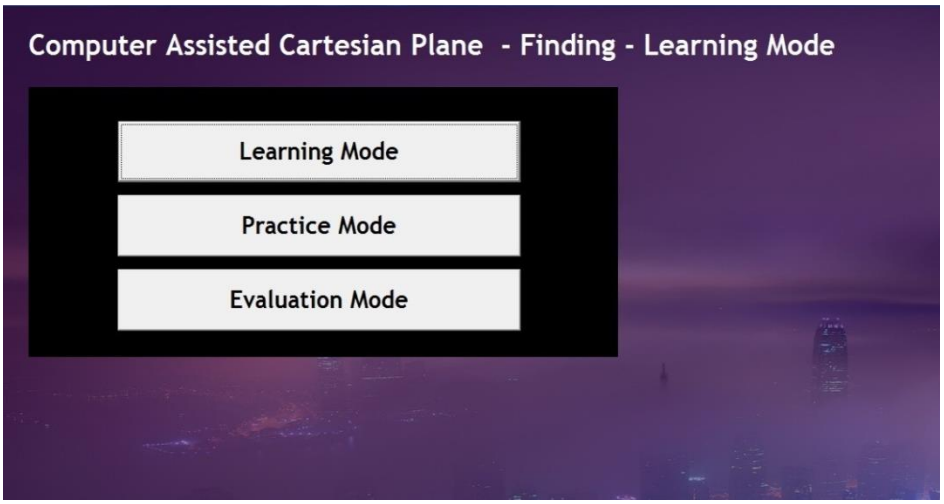


Fig 3.8: Screenshot of Finding Points Module : 3 Modes

After identifying the quadrants, the information about the arrow keys is sounded to the students with visual impairment. There will be a beep sound for every movement of keys. Manually, the student with visual impairment has to count the number of movements. A voice message like *"You have reached the x- coordinate"* will be sounded if he/she reaches the x-coordinate. After reaching the y-coordinate the system says *"You have reached the Destination point"*. Counting the movement of the pointer

along the x-axis and y-axis, the student with visual impairment can find out the coordinates (x, y).

The following pseudo-code explains the working principle of Learning Mode in *Finding Points.*

Pseudo code for Learning Mode in Finding Points Module

```
BEGIN
     Wrong Count = 0
     DISPLAY instructions
     IF userMode = "Finding"  THEN
     DISPLAY coordinates (X_Max & Y_Max)
     END IF
     If Xcount  >= X_Max   THEN
               Play Audio Beep
          ELSE
               Wrong Count + = 1
     END IF
     PLAY AUDIO  "You have reached the X coordinate"
     IF Ycount >=  Y_Max   THEN
               PLAY AUDIO Beep
          ELSE
               Wrong Count + = 1
     END IF
     PLAY AUDIO  "You have reached the destination point"
END
```

ii. Mode 2: Practice : Working Principle

Similar to Learning Mode, information about the quadrant is given by pressing the Numeric key. But no information about the key combination is provided to the visually impaired student instead of that it commands the student in voice message as *"Find x- coordinate"*. Using beep sound, the student with visual impairment has to move the pointer in the right direction. A voice message as "*You have reached the x-coordinate"* and *"Find y-coordinate*" will be sounded for the right move. The visually

impaired student must have prior knowledge of a key combination of the quadrants. It gives negative acknowledgement say *"Wrong, Try Again"* when the students with visual impairment commits an error. Using beep sound the student has to count the number of moves. Voice output like "*You have reached the Destination point*" will be given if the y- coordinate is reached. Any number of wrong movements are allowed for both Learning and Practice mode in *Finding Points*.

The following pseudo-code explains the working principle of Practice mode in *Finding Points***.**

Pseudo code for Practice Mode in Finding Points Module

```
BEGIN
     Wrong Count = 0
     HIDE instructions
     IF userMode = "Finding" THEN
     DISPLAY coordinates (X_Max & Y_Max)
     END IF
     IF  Xcount  >= X_Max   THEN
               PLAY AUDIO Beep
          ELSE
               Wrong Count + = 1
               PLAY AUDIO "Wrong, try again"
     END IF
     PLAY AUDIO "You have reached the X coordinate"
     IF Ycount >=  Y_Max   THEN
               PLAY AUDIO Beep
          ELSE
               Wrong Count + = 1
               PLAY AUDIO "Wrong, try again"
     END IF
     PLAY AUDIO "You have reached the destination point"
END
```

iii. Mode 3 : Evaluation : Working Principle

This is a test or evaluation done by the Instructor / Teacher on students with visual impairment or their own. After the Instructor / Teacher enters the coordinate of x and y, the student with visual impairment has to identify the value of x- and y-coordinates. Quadrant information alone is intimated to the visually impaired student by the system. But no intimation of the selection of arrow keys is provided; instead, it commands the student in voice message as "*Find x- coordinate*". Using beep sound, the visually impaired student has to move the pointer in the right direction. A voice message as "*You have reached the x-coordinate"* and *"Find y-coordinate*" will be sounded for the right move. A negative acknowledgement will be given to the visually impaired student for two wrong movements of the pointer. If more than two errors occur, they will go back to the main window. Once the destination point is reached, a voice message is sounded saying, "*You have reached the Destination point*".

The following pseudo-code explains the working principle of the evaluation mode in finding the point.

Pseudo Code for Evaluation in Finding Points Module

```
BEGIN
     Wrong Count = 0
     HIDE instructions
     IF userMode = "Finding" THEN
     DISPLAY coordinates (X_Max & Y_Max)
     END IF
     IF  Xcount  >= X_Max   THEN
               PLAY AUDIO Beep
          ELSE IF WrongCount = = 2
                    PLAY AUDIO "Wrong, try again"
                    BREAK
               ELSE
                    Wrong Count + = 1
     END IF
     IF Ycount >=  Y_Max   THEN
          PLAY AUDIO Beep
               ELSE IF WrongCount  = = 2
                         PLAY AUDIO "Wrong, try again"
                         BREAK
                    ELSE
```

```
                        Wrong Count + = 1
    END IF
    PLAY AUDIO "You have reached the destination point"
END
```

Table 3.6 depicts the comparison of all the three modes in Finding Points based on its operation.

Table 3.6: Comparison of Learning, Practice and Evaluation Mode in Finding Points Module

S.No	Operations	Learning	Practice	Evaluation
1	Allowed to press 1, 2, 3, 4 numeric keys to find the quadrants where the point lies.	Yes	Yes	Yes
2	Information about keys used to navigate on both the x-axis and y-axis	Yes	No	No
3	Voice message for reaching the coordinates	"Reached x-coordinate" "You have reached the Destination point" while reaching y co-ordinate	"Reached x-coordinate" "You have reached the Destination point" while reaching y co-ordinate	"You have reached the Destination point"
4	Number of errors allowed	Any	Any	Only 2

6. Class Diagram

Class Diagram is one of the static structure diagram types in Unified Modeling Language (UML). It describes the system's structure with its variables, operations, and relationship that exists between two or more classes. Variable is also called attributes or objects. Method and function are the other names for operation. The relationship between one class with another class is called inheritance, i.e., parent-child relationship. The parent class is called the main class and the child class is called a subclass. The child class inherits the property of the parent class. In object-oriented modeling, a class diagram is a building block that consists of three components namely class name, attributes, and methods. The structure of the class diagram is as follows:

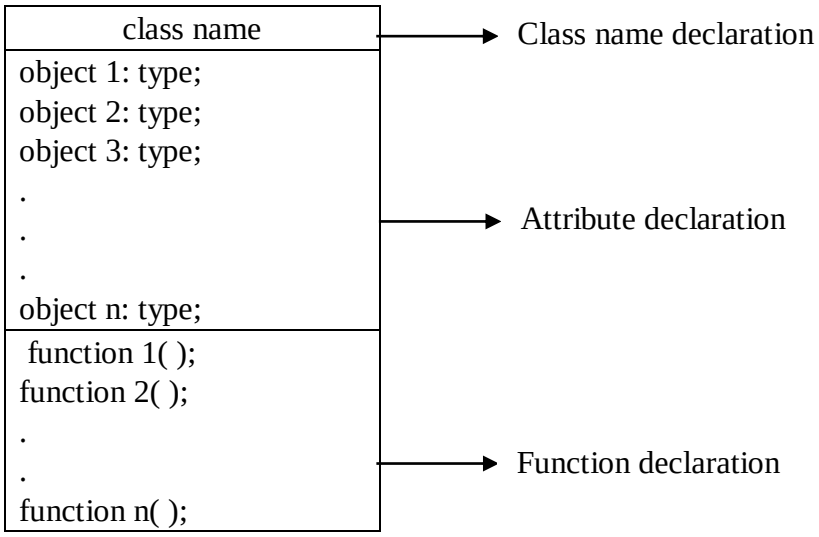


Fig 3.9: Components of Class Diagram

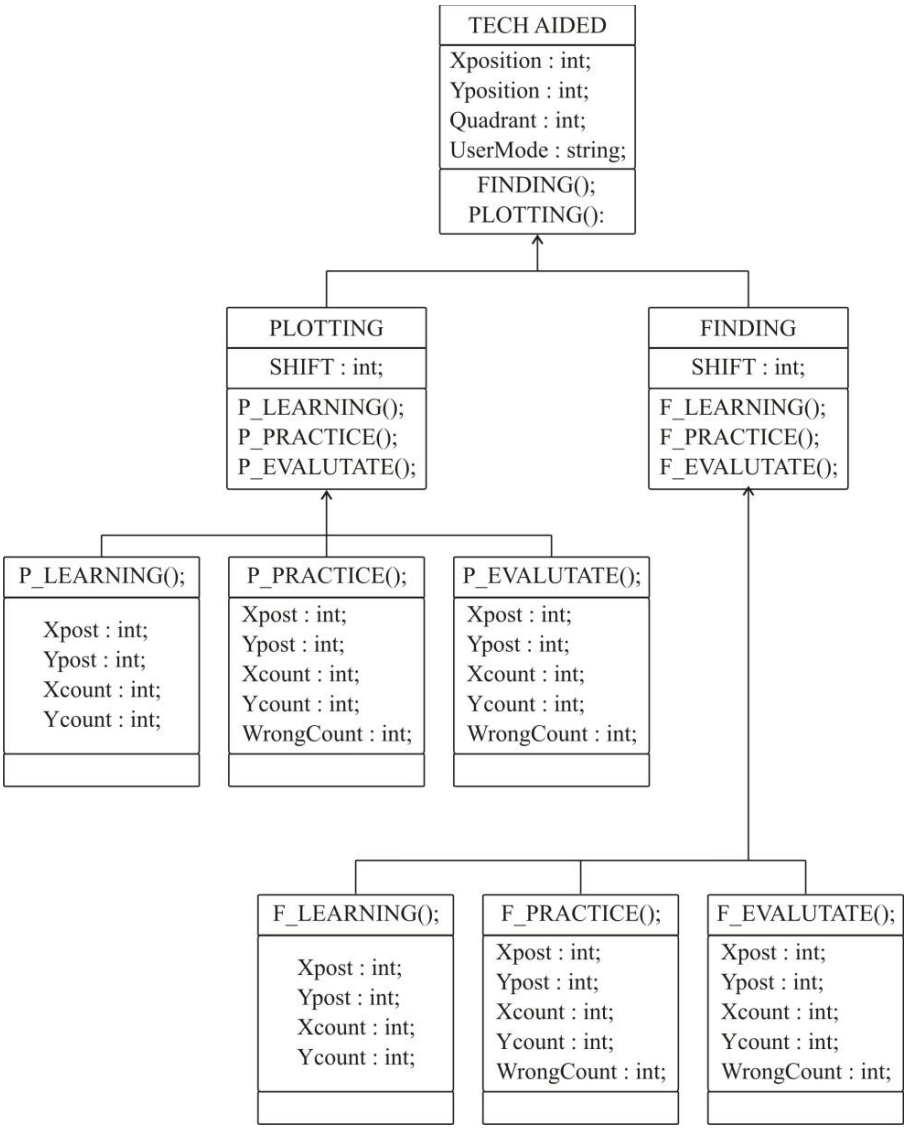


Fig 3.10: Class Diagram for Computer Assisted Cartesian Plane System

3.2 Pilot Study

After the development of Computer Assisted Cartesian Plane, the software system was demonstrated to five experts in visual impairment and 10 special teachers of students with visual impairment for their opinion and to identify effect of Computer Assisted Cartesian Plane. They suggested a few more instructions on the Execution window. A red pointer was initially displayed at the destination point, when the input was fed. This red pointer is indirectly indicating the desired outcome. Hence it was advised to remove the pointer. In addition, it was suggested to permit the user to have upto two errors while operating instead no error permission. Pointer movement restriction after getting the input, and addition of commands in essential places were also suggested. Based on the suggestions, modifications were carried out. After modification, when the system was ready to use, Pilot study was conducted among 10 students with visual impairment studying at Inclusive Schools in Coimbatore District. Pretesting, Post testing and Computer testing were conducted in a sequence. Pretest and Posttest were administered using Tactile Cartesian Plane and Computer Testing was administered using Computer Assisted Cartesian Plane. Pretest was conducted and the intervention was given for the period of one month. After intervention, Posttest and Computer testing were administered consequently. The tool used for Pretest, Posttest and Computer testing was the same. The result reveals that the tool was highly reliable and the score of Cronbach Alpha is 0.88.

3.3 Stage 2: Study the Effectiveness of Computer Assisted Cartesian Plane

After the development of the Computer Assisted Cartesian Plane system, its efficacy was analysed with the introduction of the system. For this purpose, samples have been selected and the procedure for finding out the effectiveness of the system is detailed below.

3.3.1 Site Selected

The study was conducted in Secondary Schools in the Coimbatore district of Tamil Nadu. The students with visual impairment from Grade IX to XII were selected.

3.3.2 Selection of the Sample

The sample comprised of 42 students with visual impairment with 22 Boys and 20 Girls. A stratified random sampling technique was adopted to select the sample. In the selection of the sample, Inclusion and Exclusion criteria were kept in mind. Inclusion includes students with visual impairment studying in Inclusive schools from Grade IX to XII studying in urban schools as specified in District Educational Office. The Exclusion criteria include students with visual impairment with associated disability, students studying in Private schools, visual acuity of <3/18, and those students whose parents were not willing to permit their ward to participate in the study. Keeping these factors, the researcher adopted random sampling. The total number of the sample selected was 76 and out of this, 42 students with visual impairment were finally selected.

Table 3.7 Sample Description

Std	**9th**		**10th**		**11th**		**12th**		**Total**	
Gender	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**
No. of students	3	9	9	3	7	3	3	5	22	20
%	25	75	75	25	70	30	38	62	52	48

3.3.3 Design of the Study

The design adopted in the study is a Quasi-Experimental design. It is a single group design. Here Pre observation/tests and Post observation/tests were made besides treatment. The layout of the design is:

$$\mathbf{O_1 \times O_2}$$

Here $\mathbf{O_1}$ is Pre observation

$\mathbf{O_2}$ is post observation

× is the treatment in the Experimental study.

The students with visual impairment population are very limited. Hence this research adopted a quasi-experimental design without a control group. Here in this quasi-experimental research, the independent variable is manipulated, participants are not randomly assigned to conditions or orders of condition.

3.3.4 Variables

Table 3.8 : Variables Used in the Study

Variables	Level
Independent Variable	
Designing of Cartesian Plane with two skills	i) Plotting Points ii) Finding Points
Gender	i) Boys ii) Girls
Dependent Variable	
Graph Skills	Performance in i) Plotting Points ii) Finding Points
Rating of the Device by Special Teachers and Students Teachers	i) Identifying Concepts of Cartesian Plane ii) Self-learning tool iii) Advantages iv) Usability v) Scope for teaching vi) Challenges of the system
Assesment of Performance on Computer Assisted Cartesian Plane	Plotting Points on Quadrants Plotting Points on Axes Finding Points on Quadrants Finding Points on Axes.

The study mainly intended to examine the use of Computer Assisted Cartesian Plane to teach Graph concepts. Hence the primary independent variable of the study was the manipulations of Computer Assisted Cartesian Plane using four performance in Mathematics and make students understand Graph Concepts for teaching students with visual impairment. Thus the primary independent variable is Computer Assisted Cartesian Plane.

The primary objective of the study was to evaluate whether the Computer Assisted Cartesian Plane would enable students to understand the Graph Concepts.

The outcome variables were measured based on Identifying Concepts of Cartesian Plane, Self-learning tool, Advantages, Usability, Scope for teaching, Challenges of the system using the rating scale.

Since these Graph concepts were designed exclusively for students with visual impairment, Variable control was done in terms of subject selection in terms of prior learning and uniform distribution of teaching, learning environment, and evaluation method.

The first control on sample selection was meticulously chosen by applying strict inclusive exclusive criteria such as visual acuity of < 6/18 Urban and Inclusive, and Special Schools.

The experiment was very particular in controlling the environment in which the subjects were taught the Graph concepts by the investigator with the assistance of the concerned mathematics teachers from the beginning thus prior learning or learning through other methods was restricted or controlled.

In terms of the evaluation method, the experimenter tried to control the effect of learning by applying a customized evaluation method for these students who have been a part of the experiment and thereby could generalize the results obtained only to this learning method.

3.3.5 Construction of the Tool

1. Personal Data Bank

To collect general information regarding Gender, Grade, and Name of the School, a personal data bank was developed. The tool is given in ***Annexure I.***

2. Tool to Assess the Level of Acquisition of Concepts of Cartesian Plane

This involves 14 questions related to Axes, Origin, Quadrants, Forms of Quadrants, Location of Positive and Negative Values in Axes. The tool is appended in ***Annexure-II.***

3. Assessment of Performance of Plotting Points and Finding Points on the Cartesian Plane with respect to Tactile Cartesian Plane and Computer Assisted Cartesian Plane

The test was aimed to measure the performance of students on Plotting and Finding Points on the Cartesian Plane. Sixteen questions were selected from the two skills viz. Plotting Points and Finding Points. Questions related to Finding and Plotting Points located on Quadrants and Axes were included. This test was administered as Pre Tactile, Post Tactile, and Computer Assisted test.

Scoring: For each correct response, one score and zero score for incorrect response. The tool is appended in ***Annexure III***.

4. Measuring Internal Consistency of Tool

A rating scale describing the tool in terms of identifying Concepts of Cartesian Plane, Self-learning tool, Advantages, Usability, Scope for teaching and Challenges of the system was developed to get the rating of a tool from Special teachers and the student teachers.

For rating, 35 questions were included. A four-point rating scale was given as 4- Strongly Agree, 3-Agree, 2-Disagree and 1-Strongly Disagree. The tool is appended in ***Annexure IV***.

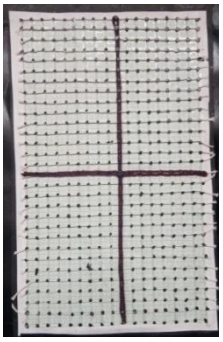
Tools were developed with the help of a literature survey and expert opinion. Necessary Modification was made after administrating the tools in the Pilot Study.

3.3.6 Implementation of the Intervention

The intervention was given to students with Visual impairment in four major areas

1. Orientation to Concepts of Cartesian Plane
2. Introduction to Cartesian Plane using tactile aid
3. Instruction for using the system for Plotting and Finding Points on the Cartesian Plane
4. Procedure for introducing Plotting and Finding Points using Computer Assisted Cartesian Plane

1. Orientation to Concepts of Cartesian Plane



Prior to the actual study, the intervention was given to the students with visual impairment for the acquisition of Concepts of Cartesian Plane viz Axes, Origin, Units, Quadrants, Forms of the Quadrants, Location of Positive and Negative values in the x-axis and y-axis, and Coordinates using a Tactile Cartesian plane. The interventions to acquire Concepts of Cartesian Plane include the following:

a. Concept of Axes

1. x- axis
2. x' axis
3. y- axis
4. y'-axis

b. Concept of Quadrants

1. I Quadrant
2. II Quadrant
3. III Quadrant
4. IV Quadrant

c. Concept of Forms of quadrants

1. I Quadrant (+,+),
2. II Quadrant (-,+),
3. III Quadrant (-,-) and
4. IV Quadrant (+,-)

d. Location of Positive and Negative values on x- axis and y- axis

1. Positive values on the x-axis
2. Negative values on the x-axis
3. Positive values on the y-axis and
4. Negative values on the y-axis

e. Concept of Coordinates

1. x - coordinate or '*abscissa'*
2. y - coordinate or '*ordinate*'

2. Introduction and Orientation on Tactile Cartesian Plane

Concepts of Cartesian Plane were introduced to the students. Texture difference was provided for each concept. Materials used in the preparation of Tactile aid have been carefully selected so as not to hurt their fingers and Palm.

Table 3.9: Different Texture used in the Preparation

S.No	Concept	Texture
1	x-axis and y-axis	Woollen Thread
2	Origin	Big dot using Glass Liner
3	Gridlines	Thread
4	The intersection between grid lines	dots using glass liner
5	Units	Labelled in Braille

3. Instruction for using the system for Plotting and Finding Points on the Cartesian Plane

The Computer Assisted Cartesian Plane was introduced to students with visual impairment. The students were allowed to explore the Computer / Laptop and find the keys which are used for operation.

Basic Steps involved in operating the Computer Assisted Cartesian Plane

1. Check the battery power in the case of the Laptop. Check the connection in the case of the Computer. CPU and Monitor should be switched on.
2. Check the headphone connection and placed the headphone in both ears. (If the student works in the class setup, a headphone is mandatory). In the case of individual work, no need for headphones.
3. Click the Computer Assisted Cartesian Plane system icon.
4. Select the Language Key (Tamil / English).
5. The system voices out "*Welcome to Computer Assisted Cartesian Plane*". A Description of the working system is given when the language '***English***' is selected.

Steps involved in Plotting Points Module in Learning Mode

1. Select the question from the menu or type the question
2. The cursor is at origin as default
3. Follow the instruction given for the selection of arrow key to reach x-coordinate
4. A beep sound can be heard for each move
5. The system voice out " *Wrong, Try again*" for each wrong move
6. The system voice out " *You have reached the x- coordinate*" after reaching the x-coordinate
7. Follow the instruction for the selection of arrow keys to reach y- coordinate
8. A beep sound can be heard for each move
9. The system voice out "*You have reached the Destination point*"
10. Repeat the process with different coordinates input
11. The same steps are voiced out as per language selection.

Steps involved in Plotting Points Module in Practice Mode

1. Select the question from the menu or type the question
2. The cursor is at origin as default
3. The system voice out " *Find x- coordinate*"
4. Use the correct arrow key to reach x- coordinate with previous knowledge
5. A beep sound can be heard for each correct move
6. The system voice out " *Wrong, Try again*" for each wrong move
7. The device voice out " *You have reached the x- coordinate*" after reaching the x-coordinate
8. Use the correct arrow key to reach **y-** coordinate
9. A beep sound can be heard for each move
10. The system voice out " *You have reached the Destination point*"
11. Repeat the process with the different coordinate input
12. The same steps are voiced out as per language selection

Steps involved in Plotting Points Module in Evaluation Mode

1. Select the question from the menu or type the question
2. The cursor is at origin as default

3. The system voice out " *Find x- coordinate*"
4. Use the correct arrow key to reach x- coordinate with previous knowledge
5. A beep sound can be heard for each correct move
6. The system voices out " *Wrong, Try again*" for each wrong move
7. The device voice out " *You have reached the x- coordinate*" after reaching the x-coordinate
8. The number of errors permitted is two
9. Use the correct arrow key to reach y- coordinate
10. A beep sound can be heard for each correct move
11. The device voices out " *You have reached the Destination point*"
12. Repeat the process with different coordinates
13. The same steps are voiced out as per language selection

Steps involved in Finding Points Module in Learning Mode

1. Select the question from the menu or type the question
2. Use Number keys 1,2, 3, and 4 to find the quadrant in which the 'point' lies
3. Follow the instruction for the selection of arrow key to reach x- coordinate
4. The device voices out " *Wrong, Try Again*" for incorrect move
5. A beep sound can be heard for each correct move
6. Count the beep sounds to find the value of x- coordinate
7. The device voices out " *You have reached the x -coordinate*"
8. Follow the instruction for the selection of arrow key to reach y coordinate
9. Count the beep sounds to find the value of **y-** coordinate
10. The device voices out " *You have reached the Destination point*"
11. Repeat the process with different coordinates
12. The same steps are voiced out as per language selection

Steps involved in Finding Points Module in Practice Mode

1. Select the question from the menu or type the question
2. Use Number keys 1,2, 3, and 4 to find the quadrant in which the point lies
3. Use the correct key to reach x- coordinate
4. The device voices out " *Wrong, Try Again*" for incorrect move
5. A beep sound can be heard for each correct move

6. Count the beep sounds to find the value of x -coordinate
7. The device voices out " *You have reached the x coordinate*"
8. Use the correct key to reach y- coordinate
9. Count the beep sounds to find the value of y- coordinate
10. The device voice out " *You have reached the Destination point*"
11. Repeat the process with different coordinates
12. The same steps are voiced out as per language selection

Steps involved in Finding Points Module in Evaluation Mode

1. Select the question from the menu or type the question
2. Use Number keys 1,2, 3, and 4 to find the quadrant in which the point lies
3. Use the correct arrow key to reach x- coordinate
4. The device voices out "*Wrong. Try Again*" for incorrect move
5. The number of errors permitted is two
6. A beep sound can be heard for each correct move
7. Count the beep sounds to find the value of x- coordinate
8. Use the correct arrow key to reach y- coordinate
9. Count the beep sounds to find the value of y- coordinate
10. The device voices out " *You have reached the Destination point*"
11. Repeat the process with different coordinates
12. The same steps are voiced out as per language selection

4. Procedure for Introducing Plotting and Finding Points using Computer Assisted Cartesian Plane

Students with visual impairment were exposed to Plot and Find points on the Cartesian Plane using Computer Assisted Cartesian Plane. During Intervention Phase, a time duration of four months was spent to teach Plotting and Finding points. Students were exposed to the various activities are described below.

a. Plotting points on quadrants

1. Plotting Points on I Quadrant
2. Plotting Points on II Quadrant
3. Plotting Points on III Quadrant

4. Plotting Points on IV Quadrant

b. Plotting Points on Axes

1. Plotting Points on x-axis
2. Plotting Points on y -axis
3. Plotting Points on x'- axis
4. Plotting Points on y'- axis

c. Finding Points on Quadrants

Finding Points on

1. I Quadrant
2. II Quadrant
3. III Quad rant
4. IV Quadrant

d. Finding Points on Axes

Finding Points on

1. x-axis
2. y-axis
3. x'-axis
4. y'-axis

e. Intervention Strategies

The investigator developed 10 Tactile Cartesian Plane since one Tactile aid can be used for only four to five students. The Tactile Cartesian Plane has been prepared using Graph Sheet, Twin Thread, Woolen Thread, Cardboard, Glass Liner, Push Pins, Cello Tape, and Glue. The preparation time for making 10 Tactile Cartesian Plane took 20 hours.

i. Intervention in the use of Tactile Cartesian plane

Students were trained in the concepts such as x-axis, y-axis, Origin, Quadrants, Form of Quadrants, Units, and Location of Positive and Negative Values on Axes.

ii. Intervention on Plotting Points on Quadrants

Students were introduced to the concepts of coordinates on Plotting it on Quadrants. For example. Plot the points (5, 4) and (-2, 7). The practice has been given to plot coordinates on the Four Quadrants.

iii. Intervention on Plotting Points on Axes

Students were introduced to the concepts of coordinates on Plotting it on Axes. For example. Plot the points (4, 0) and (0,-3). The practice has been given to plot coordinates on four Axes.

iv. Intervention on Finding Points on Quadrants

Students were introduced to the concepts of coordinates on Finding it on Quadrants. For example. Find the points (4, 5) and (0,-3). The practice has been given to find coordinates on the Four Quadrants.

v. Intervention on Finding Points on Axes

Students were introduced to the concepts of coordinates on Finding it on Axes. For example. Find the points (0, 5) and (-6, 0). The practice has been given to find coordinates on the four Axes.

5. Application of Computer Assisted Cartesian Plane

The students were instructed to switch on the device they possess (Computer/ laptop). For the students who did not have the device, the investigator has given her device for use. A demonstration was given on Computer Assisted Cartesian Plane which has voice-over with minimal Computer key usage. Then the students were oriented on the keys used, voice-over, beep sound, and selection of keys for a particular operation.

A step-by-step procedure of operating Computer Assisted Cartesian Plane in learning Plotting Points and Finding Points on Cartesian Plane was demonstrated and the students were asked to operate on their own. After the students were trained in the learning of Plotting and Finding Points on Cartesian Plane, they were given practice time to Plot and Find points. This phase consumes a period of four months. An average of 6 hours is required for a student/a group of 2-3 students for learning and practice.

Fig 3.11: Student working on Computer Assisted Cartesian Plane Software

3.4 Data Collection Procedure

Phase I

An assessment was made on two aspects namely performance on Plotting and Finding Points on Cartesian Plane using Tactile Cartesian Plane. This test was considered as Pre Tactile. The time duration taken for assessment of the performance of students using Tactile Cartesian Plane was a period of one month.

Phase II

An assessment was made on two aspects namely performance on Plotting and Finding Points on Cartesian Plane using Tactile Cartesian Plane after an intervention. This test was considered as Post Tactile.

Phase III

An assessment was made on two aspects namely performance on Plotting and Finding Points on Cartesian Plane using Computer Assisted Cartesian Plane. This test was considered as performance using Computer Assisted Cartesian Plane. The time duration taken for assessment of the performance of students using Tactile Cartesian Plane was one month and students' performance in Computer Assisted Cartesian Plane was another one month and thus making a total of two-month duration for this assessment. For all the three tests viz Pre Tactile, Post Tactile, and Computer Assisted Test, the tool (question) used was the same.

3.5 Data Analysis

For analysing the data, the following statistical techniques were used

i. For comparison of Graph Concepts of students with visual impairment t-test was used.
ii. For comparison of Plotting Points on Quadrants, Plotting Points on Axes, Finding Points on Quadrants, Finding Points on Axes, t-test was used
iii. The Repeated measures ANOVA was employed for the Performance Score of Concepts of Cartesian Plane.
iv. The Repeated measures ANOVA was employed for the Performance Score of Plotting Points on Quadrants.

v. The Repeated measures ANOVA was employed for the Performance Score of Plotting Points on Axes.

vi. The Repeated measures ANOVA was employed for the Performance Score of Finding Points on Quadrants.

vii. The Repeated measures ANOVA was employed for the Performance Score of Finding Points on Axes.

viii. 2× 2 Factorial Design ANCOVA was employed for Overall Scores in Computer by Considering Pre Tactile Score as Covariate

ix. 2×2 Factorial Design ANCOVA was employed for Overall Scores in Tactile by Considering Pre Tactile Score as Covariate

x. 2×2 Factorial Design ANCOVA was employed for Basic Concept in Computer by Considering Pre Tactile Score as Covariate

xi. 2 × 2 Factorial Design ANCOVA was employed for Basic Concept in Tactile by Considering Pre Tactile Score as Covariate

xii. 2×2 Factorial Design ANCOVA was employed for Plotting Points on Quadrants in Computer by Considering Pre Tactile Score as Covariate

xiii. 2×2 Factorial Design ANCOVA was employed for Plotting Points on Quadrants in Tactile by Considering Pre Tactile Score as Covariate

xiv. 2×2 Factorial Design ANCOVA was employed for Plotting Points on Axes in Computer by Considering Pre Tactile Score as Covariate

xv. 2×2 Factorial Design ANCOVA was employed for Plotting Points on Axes in Tactile by Considering Pre Tactile Score as Covariate

xvi. 2×2 Factorial Design ANCOVA was employed for Finding Points on Quadrants in Computer by Considering Pre Tactile Score as Covariate

xvii. 2×2 Factorial Design ANCOVA was employed for Finding Points on Quadrants in Tactile by Considering Pre Tactile Score as Covariate

xviii. 2×2 Factorial Design ANCOVA was employed for Finding Points on Axes in Computer by Considering Pre Tactile Score as Covariate

xix. 2×2 Factorial Design ANCOVA for Finding Points on Axes in Tactile by Considering Pre Tactile Score as Covariate.