

CHAPTER V

SUMMARY AND CONCLUSION

5.0 Introduction

The present study entitled “**Developing Computer Assisted Cartesian Plane to Enhance Graph Skills of Students with Visual Impairment**” is related to designing and developing of Computer Assisted Cartesian Plane using software to perform *Plotting and Finding points on Quadrants and Axes* on the Cartesian Plane by the students with visual impairment. 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. This system has voice output both in Tamil and English language. The Computer Assisted Cartesian Plane has four major components 1. *Plotting Points on Quadrants*, 2. *Plotting Points on Axes*, 3. *Finding Points on Quadrants* and 4. *Finding Points on Axes*. The study has two stages: 1. Developing Computer Assisted Cartesian Plane and 2. Studying the efficacy of Computer Assisted Cartesian Plane by introducing it to the students with visual impairment to perform various Graph skills and to rate the newly developed Computer Assisted Cartesian Plane, the same was introduced to the Special Teachers.

5.1 Rationale

Mathematics education is easily accessible to fully sighted children and it is less accessible to students with visual impairment since many of its concepts are presented graphically, and many concepts cannot be explored by touch and are put across through visual observation (Design Science 2011; Kalra et al. 2009; Maguvhe 2005; Sahin & Yorek 2009). The curriculum in regular schools is also designed for fully sighted children and is delivered largely through sight-related tasks. Acquisition of mathematical skills can be more difficult for students with visual impairment due to the abstract nature of many essential concepts and the highly visual presentation of the subject (Kapperman, Heinze & Sticken, 2000).

The most difficult mathematics lessons learned by students with visual impairment are materials that require more visual observation, such as a two-dimensional figure, three-dimensional figure, circumference, and volume (Nurmitasari, 2015). These materials make the students with visual impairment have more difficulty than other materials, although they also experience difficulties in learning other materials. Students with visual impairment should not be left from learning a graph concept due to lack or limited vision. Not only they can graph with the right tools, but they can also often do so better than their sighted peer (Kumar et.al 2001). Students with visual impairment should learn mathematical skills at the same level as their sighted peers (Tindell, 2006).

Schweikhardt (2000) noted that requirements for the successful integration of students with visual impairment into general-education mathematics environments include a notation that is simultaneously accessible by both people who are Braille readers and those who are print readers. Educators have made coordinate graphs a core component of secondary mathematics education. The emphasis on graphic literacy can be seen in many education standards. The Cartesian Plane of 'x' and 'y' works in many real-life situations. For example, if one wants to plan where to place different pieces of furniture in a room, the person can draw a two-dimensional grid and use an appropriate unit of measurement. Hence the concept of the Cartesian Plane is vital to any learner. Students with visual impairment should know how to plot coordinates of points and locate their position in the Cartesian Plane. As mentioned, Graphs are taught to students with visual impairment using Tactile graphs which consumes time, planning, and in nutshell a tedious process.

In today's context, the technology boom has produced an abundance of tools to assist with learning and teaching, including those useful to teachers of students with visual impairment. High-quality teaching incorporates tools to help students with and without visual impairment to access and understand advanced mathematics to the best of their ability. Often, itinerant teachers/Special teachers to the students with visual impairment may have only one Braille reader in their entire careers and will have very little time to tackle a trial-and-error approach to teaching such students (Zhou, Parker, Smith, & Griffin Shirley, 2011). For a classroom teacher who has students with visual

impairment, the presence of technology in the classroom is not optional but necessary. Many mathematicians, such as Buteau, Marshall, Jarvis, and Lavicza (2010), believe proficiency in advanced mathematics has become synonymous with proficiency in corresponding technology. Technology can eliminate the tediousness of calculations, allowing students to focus more on conceptual understanding. Students with visual impairment must have access to technology that provides these same supports, and perform mathematics to the best of their ability.

With this premise, a survey of literature related to technology-based Cartesian Plane was explored in the Indian Context. It was hardly available. Hence this investigation was focused to develop Computer Assisted Cartesian Plane to enhance the graph skills of students with visual impairment and the effect of this newly developed software system for Cartesian Plane was examined with the help of students' participation and performance in Plotting and Finding Points in this Experimental study.

5.2 Objectives

The objectives of the study were to

1. Develop Computer Assisted Cartesian Plane to enhance graph skills of students with visual impairment.
2. Find out the level of acquisition of Concepts of Cartesian Plane among students with visual impairment before and after the introduction of Computer Assisted Cartesian Plane.
3. Compare mean scores of Plotting Points on Quadrants and Axes with respect to Tactile Cartesian Plane (Pretest) and Computer Assisted Cartesian Plane.
4. Compare mean scores of Finding Points on Quadrants and Axes with respect to Tactile Cartesian Plane (Pretest) and Computer Assisted Cartesian Plane.
5. Compare mean scores of Plotting Points on Quadrants and Axes with respect to Tactile Cartesian Plane (Posttest) and Computer Assisted Cartesian Plane.
6. Compare mean scores of Finding Points on Quadrants and Axes with respect to Tactile Cartesian Plane (Posttest) and Computer Assisted Cartesian Plane.
7. Study the influence of Gender on Plotting Points on Quadrants and Axes with respect to Tactile Cartesian Plane and Computer Assisted Cartesian Plane.

8. Study the influence of Gender on Finding Points on Quadrants and Axes with respect to Tactile Cartesian Plane and Computer Assisted Cartesian Plane.
9. Study the influence of Grade on Plotting Points on Quadrants and Axes with respect to Tactile Cartesian Plane and Computer Assisted Cartesian Plane.
10. Study the influence of Grade on Finding Points on Quadrants and Axes with respect to Tactile Cartesian Plane and Computer Assisted Cartesian Plane.

5.3 Method

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

Stage 1: Design and Development of Computer Assisted Cartesian Plane

Computer Assisted Cartesian Plane system has been developed for students with visual impairment to plot the coordinates of the x- and y-axis and to find the coordinates in the digital platform instead of the traditional tactile approach. The Computer Assisted Cartesian Plane system has been developed using Visual Basic 6.0. Minimal Keys are used for the operation namely Shift key, Escape Key, Arrow Keys, Number Keys, and Comma Key. Each key is having its own command. Other than these, the common keys such as Delete Key and Backspace keys to delete when it is wrongly typed and to adjust the space were used. Since the system is self-instructional in nature, the system voices out each command depending on language selection. The entire Computer Assisted Cartesian Plane system is divided into two modules namely Plotting Points and Finding Points. Further, each of these modules has three modes viz, Learning, Practice, and Evaluation. As mentioned earlier, the modules are developed individually and clubbed together finally to make the system a single unit.

For all the modules, the execution window is split into two columns. On the left side, the working area of the graph in which the Cartesian plane is there. On the other side, instructions are displayed. There is a drop-down box available on the right side above the instructions, either to select the readily available coordinates or the user can

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

Module 1: Plotting Points

Once the Plotting Points module is selected, the execution window opens and the cursor blinks on the input box and simultaneously voices out to provide input meaning x- and y-coordinates. In the input box, students with visual impairment have to enter coordinates manually or select the readily available coordinates. After input, by pressing the shift key the system analyses and fixes the point internally and the pointer moves to the origin as default. Using the right combination of keys for each quadrant, the student has to reach the destination point. The system's voice out when the student reached x- and y- coordinates. A beep sound will be heard for each movement of the pointer representing one unit.

Module 2: Finding Points

Unlike the Plotting Points, students with visual impairment do not know the coordinates plotted by the system. The input (x- and y-coordinates) is randomly given by the system or given manually by the Instructor/Teacher. After getting the input, the students with visual impairment have to identify the location of the point on which quadrant it lays and for this purpose; the student has to press numeric keys: 1, 2, 3, and 4 followed by the Shift key. If the point lies in a particular quadrant, the system voices out the quadrant number. If not, no response from the system and the student has to proceed further for identification. If the point lies on Axes, the student has to press arrow keys to identify the location of the point on which Axes it lies. After finding the point on the Quadrant or Axis, the student has to Find the point by using appropriate arrow keys. Here the student has to count the beep sound to find the coordinate value. Each Beep sound represents one unit.

The system voice out Positive Acknowledgement such as Good, Reached Destination, and Negative Acknowledgement such as Wrong, Try Again wherever necessary.

As mentioned earlier, each module has three modes where each mode has its uniqueness. In Learning Mode, step-by-step information is given, whereas in Practice and Evaluation mode, where no information is provided. Any number of errors are allowed in Learning and Practice Mode whereas only two errors are permitted in Evaluation mode.

Stage 2: Study the Effectiveness of Computer Assisted Cartesian Plane

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

a. 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.

b. 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

c. 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:

$$O_1 \times O_2$$

Here O_1 is Pre observation

O_2 is post observation

\times 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.

d. Variables

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.

e. 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 the knowledge about 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 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 concepts 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.

f. 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, an 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 the tactile Cartesian plane.

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

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.

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 the Intervention Phase, time duration of four months was spent to teach Plotting, and Finding points. Students were exposed to various activities.

5.4 Findings

In the study, three types of tests have been administered. They are assessment of Graph concepts using Tactile Cartesian Plane before and after intervention and Computer Assisted Cartesian Plane. Tests are termed as Pre Tactile(Before Intervention), Post Tactile (After Intervention); and Computer Assisted test/score (After the introduction of Computer Assisted Cartesian Plane) Here pretest was conducted using Tactile Cartesian Plane, posttest was conducted in two formats: 1) Tactile Cartesian Plane and 2) Computer Assisted Cartesian Plane.

The major findings that emerged out of the study are:

Result1: Efficiency of the Computer Assisted Cartesian Plane

1. Computer Assisted Cartesian Plane was found to be error-free indicated by the successful installation of the system. Only when the developed system is error-free, it will be installed.
2. As regards the time complexity, each module of the programme performs linear searching
3. As regards audio and video features, the audio and the video output of the programme are accessible
4. In analysing the data from visually impaired students, they opined that the Computer Assisted Cartesian Plane has simple features to learn graph concepts independently.

Result 2: Rating of Computer Assisted Cartesian Plane

1. Special Teachers and students teachers responded to the question if students with visual impairment can directly use Computer Assisted Cartesian Plane without prior Tactile Orientation. Nearly 99% of the respondents stated that students with visual impairment need tactile orientation before entering into Computer Assisted Cartesian Plane.
2. Among the respondents, 83.3% rated that the newly developed Computer Assisted Cartesian Plane system is a self-learning tool

3. Examining the advantage of the newly developed system in terms of three modes, minimal key usages, accessibility at any time and anywhere, nearly 78% of the respondents expressed that Computer Assisted Cartesian Plane has many advantages to perform graphs by the students with visual impairment.
4. Computer Assisted Cartesian Plane was assessed its usability in terms of Self instructional, Meeting the objectives for which this system developed, Time Effectiveness, Easier application and Supplementary to Tactile Cartesian Plane. The result presents that 75.3% of the respondents agreed its usability with the features mentioned above.
5. As regards the scope of this tool for usage by other stakeholders such as Parents, Regular teachers, and Sighted Students, 72.9% expressed that the system can be useful.
6. Examining the challenges of using the system in terms of Prior computer knowledge, distraction due to monotone, limiting tactual mode of learning, less interaction with Peers and Special Teachers, 72.8% agreed that this newly developed tool has the challenges.

Result 3: Efficacy of Computer Assisted Cartesian Plane in Graph Concepts

1. When analysing the student's score on the acquisition of Concepts of Cartesian Plane, the results indicate that the Post Tactile Score (M =12.40) is higher followed by Computer Assisted Score (M = 12.29) and then Pre Tactile Score (M=3.29).
2. In Plotting Points on Quadrants, the overall performance of the students showed significant improvement from Pre Tactile to Post Tactile and then to Computer Assisted score (Mean: Pre Tactile -0.76; Post Tactile- 2.86; Computer Assisted -3.07)
3. When analysing the overall score for the Plotting Points on Axes for students, the results indicate that the Post Tactile score (M =2.67) is higher followed by Computer Assisted Score (M = 2.64) and then Pre Tactile Score (M=0.05).
4. In Finding Points on Quadrants, the overall score of students indicates that they secured a higher score in Computer Assisted (M=2.76) a Pre Tactile Score (M=0.60), and Post Tactile Score (M=2.50).

5. The overall results of Finding Points on Axes showed that the Post Tactile mean score has scaled up to 2.62 when compared to Computer Assisted score which is 2.29 and the Pre Tactile score 0.07.

Result 4: Repeated Measures Analysis of Variance (ANOVA) for the Performance of Students in Graph Concepts

1. The F value of ANOVA for Plotting Points on Quadrants revealed that there is no difference between the pairs of Post Tactile and Computer Assisted Score. However, for the pairs of Pre Tactile and Post Tactile, the mean difference is 2.10 indicating Post Tactile is higher. Similarly the pairs of Pre Tactile and Computer Assisted, the mean difference is 2.31, indicating Computer Assisted Score is higher.
2. The F value of ANOVA for Plotting Points on Axes revealed that there is no difference between the pairs of Post Tactile and Computer Assisted Score. However the pair of Pre Tactile and Post Tactile, the mean difference is 2.62 indicating Post Tactile is higher. Similarly, for the pairs of Pre Tactile and Computer Assisted, the mean difference is 2.60 indicating Computer Assisted is higher.
3. The F value of ANOVA for Finding Points on Axes revealed that there is a difference between the pairs of: Pre Tactile and Post Tactile; Pre Tactile and Computer Assisted; Post Tactile and Computer Assisted. For the pair of Pre Tactile and Post Tactile, the mean difference is 2.50 revealing Post Tactile is higher. For the pairs of Pre Tactile and Computer Assisted, the mean difference is 2.21 indicating, Computer Assisted is higher. Though the mean difference between Post Tactile and Computer Assisted is very minimal (0.33), Post Tactile has some advantages.
4. The F value of ANOVA for Finding Points on Quadrants revealed that there is a difference between the pairs of: Pre tactile and Post Tactile; Pre Tactile and Computer Assisted; Post Tactile and Computer Assisted. For the pair of Pre Tactile and Post Tactile, the mean difference is 2.10 stating Post Tactile is higher. For the pairs of Pre Tactile and Computer Assisted, the mean difference is 2.31 concluding Computer Assisted is higher. Though the mean difference

between Post Tactile and Computer Assisted is very minimal (0.21) Computer Assisted has some advantages.

Result 5: Influence of Gender/Grade and their resultant interaction on Graph Concepts by Analysis of Covariance (ANCOVA)

1. 2x2 ANCOVA for Concepts of Cartesian Plane with respect to Post Tactile score reveals the following results.
 - i. Gender did not influence on Concepts of Cartesian Plane
 - ii. Grade did not influence on Concepts of Cartesian Plane
 - iii. Hence Concepts of Cartesian Plane were found to be independent of interaction between Gender and Grade.
2. 2x2 ANCOVA for Concepts of Cartesian Plane with respect to Computer Assisted Score reveals the following results.
 - i. Gender did not influence on Concepts of Cartesian Plane
 - ii. Grade did not influence on Concepts of Cartesian Plane
 - iii. Hence Concepts of Cartesian Plane were found to be independent of interaction between Gender and Grade.
3. 2x2 ANCOVA for Plotting Points with respect to Post Tactile score reveals the following results.
 - i. Gender did not influence on Plotting Points
 - ii. Grade did not influence on Plotting Points
 - iii. Hence Plotting Points were found to be independent of interaction between Gender and Grade in Plotting Points.
4. 2x2 ANCOVA for Plotting Points with respect to Computer Assisted Score reveals the following results.
 - i. Gender did not influence on Plotting Points
 - ii. Grade did not influence on Plotting Points
 - iii. Hence Plotting Points were found to be independent of interaction between Gender and Grade in Plotting Points.
5. 2x2 ANCOVA for Finding Points with respect to Post Tactile score reveals the following results.
 - i. Gender did not influence on Finding Points

- ii. Grade did not influence on Finding Points
 - iii. Hence Finding points were found to be independent of interaction between Gender and Grade in Finding Points.
6. 2x2 ANCOVA for Finding Points with respect to Computer Assisted Score reveals the following results.
- i. Gender did not influence on Finding Points
 - ii. Grade did not influence on Finding Points
 - iii. Hence Finding points were found to be independent of interaction between Gender and Grade in Finding Points.

5.5 Discussion

In the present study, the Computer Assisted Cartesian Plane is defined as a graph that is an interactive display giving a learner access to nonverbal relationships between parts of data within and between dimensions. This is also termed auditory graph with particular reference to Cartesian Plane that is an accessible alternative to visual and tactile graphs.

Computer technology is used in this research study and the same was evaluated if audio graphing technology is suitable for students with visual impairment.

The effectiveness of the newly developed Computer Assisted Cartesian Plane which has audio input and output is compared with the traditional tactile graph.

Vision takes a dominant role in learning mathematical graphs. Even in the technology era, when assistive technology is a boon to students with visual impairment, most of the students are non-participant in the mathematics class because of the inaccessibility of the content. Graphs are a rationally critical part of STEM areas but have an impact on day-to-day life. But Graphs are not accessible to persons with visual impairment.

Upon review of previous research studies, Bonebright et al (2001) experimented with the method of sonification of the x-axis. Sonification here means the use of non-speech audio to convey visual information in the form of data. The present investigation is also in line with their study using sonification, non-speech sound, and also certain audio output.

Kim, Lee, & Seo, (2019) stated that designing a method for the audio presentation of mathematical elements of the graph is a mostly unexplored area. The basic mathematical elements of the Cartesian coordinate system are x- and y- axes, the coordinates of points on the Quadrants. In their study, sonification was used to represent the y-axis with pitch, and the x-axis was represented with time. Stereo panning was added to locate the x-axis position. In the present investigation, the system has been designed using the audio output and beep sound which is here termed as sonification. In sonification, there is no pitch for the different moves, only sample amplification of beep sound. The present study results indicate students with visual impairment could perform Cartesian Plane with audio input and out with sonification support. This result is in agreement with the experiment result of Jeongyeon Kim et al (2019) revealing drawing accuracy of students with visual impairment with speech information is 94.58% as against 76.88% accuracy without speech information. As Previous authors' experiment results suggest a set of guidelines for designing auditory graphs, the present study also provides guidelines in terms of audio instruction "Welcome " to the Computer Assisted Cartesian Plane and immediately module page is open, voicing out simultaneously the module viz, Plotting and Finding Points. Step by step audio instruction is given to select the module.

Audio instruction to use Learning mode, Practice mode, and Evaluation mode has been provided step by step. In learning, necessary instructions are provided. But Practice and Evaluation mode provided with an audio command for further move.

In the present study tactile graphs have been used with a view of allowing the students with visual impairment to gain clarifying audio information without sighted assistance. Dick & Kahiak (1997) and (Jones, Minogue, Tretter, Negishi, & Taylor, 2006) reported that many STEM concepts such as direction, shape, and quantity are taught in ways that rely on visual reference posing severe access issues for students with visual impairment unless graphics are provided in a tactile format. The present investigation has the same objectives of using the tactile graphs before leading to audio graphs and thus is in agreement with earlier studies.

Thus the current study reiterates that it is extremely important for students with visual impairment to have access to the content contained in the tactile graph, though the preparation is time-consuming and tedious.

5.6 Suggestions

1. The present study is technology-based for teaching-learning of graph skills to students with visual impairment. Further study may be pursued as synthesized voice input and output with a refreshable display.
2. A research study on how assistive products improve an individual's functioning and promote independence and their wellbeing may be pursued.
3. Further research may be conducted on the impact of Assistive technology to respond to the challenges that arise from an accident.
4. For educational purposes, studies on various approaches in assistive technology such as sensor-based, image processing-based, and application-based may be conducted.

5.7 Theoretical and Practical Implications

In the present research, the anticipated outcome that students with visual impairment to perform the Graph skills viz Plotting and Finding Points independently has been happened. The procedure of using the Computer Assisted Cartesian Plane might be used as a set of guidelines for application by teachers and students with visual impairment. The guidelines can be in the form of Print and Braille. The training institutes may incorporate a component of Assistive technology for the students with visual impairment in the curriculum. The study outcome might help the Teachers and Teacher educators to get reoriented to enrich their knowledge in the latest development in the field.

The students with visual impairment are mostly deprived of Graph skills due to their visual orientation. This study proved that students with visual impairment can do graph skills at the high school level independently. Another practical implication is that this system is designed to use it in an inclusive school. The inclusive classroom teacher can use the system to demonstrate graph skills to other students in the

classroom. This can change the attitude of the inclusive classroom teachers and peers towards students with visual impairment and they consider this system as an effective learning system for all.

The Implication to Textbook Writers

The application of technology to education particularly to draw graphs is a recent phenomenon in Special Education in the Indian context. Books by Indian authors in Special Education are being slowly emerged. The development of this system and its efficacy in performing graph skills by persons with visual impairment evidenced in the study has implications to book writers. The writers can incorporate this indigenous development in their writings.

Implication for Product Development

The user and the special teachers in the study expressed the usability and the advantage of this system. The prototype developed in the research has scope for product development and the developers can get detailed guidance from the research team on how to design user-friendly devices for wider usage.

5.8 Recommendation

1. This study proved that Assistive technology can be a level player and a great equalizer for students with visual impairment. Hence students with visual impairment need to acquire a plethora of technical skills that will provide alternatives for collecting and communicating information. The study recommends that the teacher training curriculum for students with visual impairment may be designed with the instruction in the application of Assistive technology, information on its availability, and maintenance.
2. The newly developed Computer Assisted Cartesian Plane has the design that would be useful for any child in the inclusive classroom. Hence the study recommends that any researcher developing assistive technology for educational purposes may give importance and adopt the universal design principles so that a single aid/ device can be used by the whole classroom and thus minimize discrimination of disabled and non-disabled in the inclusive school set up.

3. Many research studies indicate that Assistive technology is boon to persons with disabilities giving promising means to accommodate barriers to independence. But it is adverse that such devices are underutilized by persons with disabilities and the main reason is lack of knowledge and skill among educational personnel. Hence this study recommends the educators and related stakeholders to be well oriented on the benefit of assistive technology and encourage students with disabilities to use the same which would be an equalizer in mainstream education.
4. The Government of India may give financial assistance to improve any prototype developed and make it available as a product to educate students with different categories of disability on par with their non-disabled counterparts. The cost of the devices is also a barrier and the government may address the issue of cost and availability.

5.9 Conclusion

Vision enables access to information helping the development of mathematical concepts. Many basic mathematical concepts that describe visual phenomena are taught orally to students with visual impairment. Students with visual impairment face more challenges to understand and grasp directional and spatial concepts. Consequently, the students with visual impairment get fewer experiences of how mathematical concepts are used in daily life communication than sighted children. There is a general opinion that students with visual impairment cannot graph, and cannot do geometric construction. The reason for such attitude is that curricular graphs and geometric materials are visual in nature and hence they face considerable challenges in reading them. Despite many legal provision nationally and internationally that learning materials are to be accessible, many mathematics textbooks which have visual images for important content is not transcribed in either Braille format or digital format of the texts. Technology offers new opportunities and accessibility for students with visual impairment by complementing the use of tactile devices. The present study aimed to develop a digitally enhanced learning tool to perform graphs with reference to Cartesian Plane. The study results evidenced that the newly developed technology-based tool is making the learning process more encompassing, more participatory, and

more collaborative. Thus the study stands as a testimony that students with visual impairment not only learn graphs but they can draw graphs independently when the right tools are provided.

This study is a small but significant contribution in teaching mathematics to students with visual impairment!.