CHAPTER I
INTRODUCTION

1.0 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.

In this Chapter, the details in respect to Blindness rates globally and in India, Historical Perspectives of Education for Blind, Education of the Blind in Pre - and Post-Independent India, Inclusive Education in India, Use of Technology in the Education of Visually impaired, Use of Technology in the Employment of Visually Impaired, Use of Technology in the Classroom, STEM Education for Visually Impaired, Science Education for the Blind, Importance of Mathematics Education, Technology and Use of Technology in Teaching Subjects for Blind Students, Rationale for the Study, Statement of the Problem, Terms used in the study, Objectives, Hypotheses, Scope of the study, Delimitations and Organization of the study are described.

1.1 Blindness Rates Globally and in India

The National Blindness and Visual Impairment Survey 2015-2019 was conducted to provide evidence about the present status of blindness and visual impairment in India. The survey was planned by the Ministry of Health and Family Welfare, Government of India. Dr. Rajendra Prasad Centre for Ophthalmic Sciences, AIIMS, and New Delhi was responsible for planning and executing the fieldwork, monitoring, analysis, and report writing of the survey. The survey was conducted in partnership with various reputed Eye Health Institutes of the country. The Survey was conducted in aged ≥ 50 years population using the Rapid Assessment of Avoidable Blindness (RAAB) strategy in 31 districts of 24 States/Union Territories of India from September 2015- June 2018. This house-to-house survey was designed to generate representative data for the sampled districts as well as for India. Both rural and urban areas were included in this survey. An additional survey was conducted in the 0-49 years age group in Jan-Feb 2019. This survey was conducted in 6 districts selected from six zones (north, south, east, and west, central and northeast) of India. The results of both surveys, in the 0-49 age group and≥ 50 years population, were used to estimate the prevalence of blindness and visual impairment in India across all age groups.

Prevalence of blindness and visual impairment in the overall population was 0.36%, severe visual impairment was 0.35%, moderate visual impairment was 1.84%, early visual impairment was 2.92%. Estimated moderate-severe visual impairment in the overall population was 2.19% and that of visual impairment was 2.55%. The estimated prevalence of pinhole blindness in the overall population of India was 0.32%. (National Blindness and Visual impairment survey India 2015 -2019 - A Summary Report).

India was the first country in the world to launch the National Program for Control of Blindness in 1976 to reduce blindness prevalence to 0.3% by the year 2020. In 1999, the WHO launched Vision 2020: The Right to Sight, a joint endeavor with IAPB, to eliminate avoidable blindness by 2020. In 2013, World Health Assembly adopted Universal Eye Health: Global Action Plan 2014-19 intending to reduce the prevalence of avoidable visual impairment by 25% by 2019 compared to the baseline prevalence in 2010. India has implemented a series of measures in its ongoing National Program for Control of Blindness and Visual Impairment (NPCB & VI) to combat blindness and visual impairment

In 2020, an estimated 43.3 million people were blind, of whom 23.9 million were estimated to be female. WHO (2020) estimated 295 million people to have moderate and severe vision impairment, of whom 163 million were female; 258 million to have mild vision impairment, of which 142 million were female; and 510 million to have visual impairment from uncorrected Presbyopia, of which 280 million were female. Globally, between 1990 and 2020, among adults aged 50 years or older, the age-standardized prevalence of blindness decreased by 28·5% and the prevalence of mild vision impairment decreased slightly, whereas the prevalence of moderate and severe vision impairment increased slightly. In this period, the number of people who were blind increased by 50·6% and the number with moderate and severe vision impairment increased by 91·7%. By 2050, it is predicted that 61·0 million people will be blind, 474 million will have moderate and severe vision impairment, 360 million will have mild vision impairment, and 866 million will have uncorrected Presbyopia. (WHO, 2020).

1.2 Historical Perspectives of Education for Blind

The visually impaired people have passed through various stages of being treated as rejects of society to being recognized as talented persons who were not inferior to their sighted counterparts. From their status of being more akin to objects than living beings in antiquity, the visually impaired have passed through the phases of getting social protection during the Judaic and Christian periods in the West, more for consideration of body than soul (Kirtley, 1975). Before the 80s blind people were mainly self-taught, often being given appropriate assistance. France was the cradle of new attitudes towards the blind and started the first school for blind children. The philosophical groundwork was laid by Diderot, an enlightened philosopher, and the physician to King Louis XV. In 1749, he published ‘Letter on the Blind for the Use of Those Who See’.

The next giant step was taken in Paris in 1784 by Valentin Hauy when he established the Institution des Jeunes Aveugles (Institution for Blind Youth). Admiration for their competence, not pity for their blindness, was what Hauy hoped to engender for his students. Despite political upheavals in France and the life of his school, Hauy’s contribution was a lasting one. He founded the first school for blind children, which was to become a model. He emphasized reading and fostered the development of embossed print. Believing in the vocational potential of blind people, he introduced vocational training in his school. Education of the blind children received a further boost by 1834 with the successful adaptation and development of the embossed dot code by Louis Braille, a Frenchman, himself blind. Until this time, blind people did not have an efficient system of reading and writing. Therefore the code which bears Braille's name still taught around the world, ushered in an era of easier communication among the blind themselves opening the doors for the acquisition of information and knowledge through the sense of touch. Hauy's success led to the establishment of similar institutions in Europe, including the first school for the blind in Liverpool, England, in 1791. Almost half a century after the founding of Hauy's institution, the first school for blind children was opened in the United States. Three private schools were then founded almost simultaneously. They are presently known as Perkins School for the Blind (1829), the New York Institute for the Blind (1831), and Overhrook School for the Blind (1833).

1.3 Education of the Blind in Pre- and Post-Independent India

The residential model was rapidly replicated, not only in the USA but also beyond the shores of Europe and North America. The missionaries arrived in Asia and other parts of the world before the turn of the 19th Century, to offer education and rehabilitation services to blind people. In India, Miss Annie Sharp, a Christian missionary from England, founded the first school for the blind in Amritsar in 1887. There were just four schools for the blind at the turn of the Century. But the efforts in this direction by the voluntary organizations and the Christian missionaries continued. By 1944, when the report on blindness in India was submitted, there were 32 schools in undivided India. Most of these schools were being managed by private agencies, with grants from some state governments.

1.4 Inclusive Education in India

Inclusive education (IE) is a new approach towards educating children with disability and learning difficulties with that of normal ones within the same roof. It seeks to address the learning needs of all children with a specific focus on those who are vulnerable to marginalization and exclusion. It implies all learners - with or without disabilities being able to learn together through access to common pre-school provisions, schools, and community educational settings with an appropriate network of support services. This is possible only in a flexible education system that assimilates the needs of a diverse range of learners and adapts itself to meet these needs (Sanjeev & Kumar, 2007).

Providing all students in general education classes with high-quality instructions, intervention, and support is a hallmark of inclusive education (Vorapanya & Dunlap, 2014). Inclusive schools have a collaborative and respectful school culture where students with disabilities are presumed to be competent, develop positive social relationships with peers, and are full participating members of the school community (Lamichhane, 2017).

The principle of inclusive education was adopted at the "World Conference on Special Needs Education: Access and Quality" (Salamanca, Spain 1994) and was restated at the World Education Forum (Dakar, Senegal 2000). The idea of inclusion is further supported by the United Nation's Standard Rules on Equalization of Opportunities for Person with Disability Proclaiming Participation and equality for all. Of late, a consensus has emerged among Indian intellectuals and pedagogues for adopting inclusive education in mainstream schools.

Inclusion is a process of addressing and responding to the diversity of needs of all children, youth, and adults through increasing participation in learning, cultures, and communities, and reducing and eliminating exclusion within and from education. It involves changes and modifications in content, approaches, structures, and strategies, with a common vision that covers all children of the appropriate age range and a conviction that it is the responsibility of the regular system to educate all children. Complete inclusion in a regular school means where the child is completely a unified part of the existing educational scenario, hardly identifiable at the first glance. India has been working towards legalizing the acceptance of the child with a disability through its Acts and Policies over the decades. Yet this has been slow. NCERT with the references of the documents framed by UNICEF has ultimately led to the development of the National Curriculum Framework for School Education (2005), a contemporary guiding document for School Education in India.

Some of the contemporary developments in the recent decades that have shaped the concept of inclusion in India are:

- 2006: The UN Convention on the Rights of Persons with Disabilities is adopted and ratified by India; however, they did not adopt or ratify the protocol. Article 24 of the Convention discusses the importance of inclusion.
- 2006: The National Policy for People with Disabilities changes special schools into resource centers for people with disabilities and teachers. It also attempts to bridge the service gap between rural and urban areas by creating more District Disability and Rehabilitation Centers.
- 2008: Inclusive Education of the Disabled at the Secondary Stage (IEDSS) replacing the 1974 IEDC.
- 2009: The Right to Education Act, which was originally drafted in 2005, was not passed until 2009, and was put into full effect in 2010. The supreme court upheld the constitutionality of the act in 2012. This act was not disability- specific, but rather included people with disabilities. (Dr.Renu Malaviya and Dr.TulikaTalwar)

1.5 Use of Technology in the Education of Visually Impaired

Teachers of the Visually Impaired teach a wide array of academic and functional skills that are necessary for supporting students with visual impairment and encouraging their development (Koenig & Holbrook, 2000). These skills are outlined by the Expanded Core Curriculum (Hatlen, 1996) and include traditional curriculum skills, like literacy, as well as behavioural skills, like social interaction and self- determination (Lewis, Savaiano, Blankenship, & Greeley-Bennett, 2014)., (Sapp & Hatlen, 2010). However, teaching may be overwhelming for educators who have to build activities that address several skills at once.

Technology motivates students to engage and learn and can be a powerful tool for instruction in the areas defined by Expanded Core Curriculum (Hartz, 2000). However, as the digital landscape for assistive technologies is constantly changing, Teacher of Students with Visual Impairment may spend a considerable amount of time researching how their existing tools work (Ajuwon, Meeks, Griffin-Shirley, & Okungu, 2016), (Stangl, Kim, & Yeh, 2014) while trying to keep up with new technology releases (Baker, Milne, & Ladner, 2019) Even with new technology available, students may resist using tools that make them stick out from their peers and opt for more discrete options (Baker et al., 2019), (Branham & Kane, 2015)., (Shinohara & Wobbrock, 2011).

Assistive technology is an interdisciplinary field of knowledge comprising products, resources, methodologies, strategies, practices, and services that aim to promote functionality for visually impaired people with regard to autonomy, independence, quality of life, and social inclusion (Cook & Hussey, 2002). Information technology, the main assistive technology resource applied to educating students with visual impairment, can be defined as computers with programs that allow students to access the digital environment, promoting individual life and social/education inclusion. Inclusive schools provide all students with a regular classroom, thus ensuring adequate and challenging educational opportunities fitted to their abilities and needs, according to the principle of educational inclusion defined in the Salamanca Declaration (World Conference on Special Needs Education: Access and Quality. The Salamanca Statement and Framework for Action on Special Needs Education. Salamanca, Spain: United Nations Education, Scientific, and Cultural Organization and Ministry of Education and Science Spain; 1994. (Stainback & Stainback, 1996)

1.6 Use of Technology in the Employment of Visually Impaired

The issue of workplace participation and assistive technology has been a growing area of work in the recent decade, including in the ICTD field which has seen both the development of new technologies as well as commentary on issues of technology and disability in the recent years. Social and economic inclusion of people with vision impairments has been something that industrialized and developing countries alike have struggled with over the past several decades, though with the increase in access to assistive technology (AT) in the recent past, the scope of participation has increased significantly.

People with disabilities who are employed often are forced to work fewer hours than their peers; well under one-fifth (17%) work full-time, compared with the nearly two-thirds (63%) of people without disabilities (Rehabilitation Research and Training Centre on Workforce Investment and Employment Policy for Persons with Disabilities).

On social science research in the last decade on corporate culture and its impact on the employment of people with disabilities, as well as on the impacts of assistive technology on jobs for people with disabilities since the 2000s, but most such work restricted to the developed world. In general, the work on disability has been growing in the past decade, but the focus has generally been on issues of disability measurement or sizing up the economic effect of disability on labor markets or the relationship to poverty more broadly. In particular, social science work on vision impairment in India has not been very prominent outside of public health research, and while there is some work on assistive technology related to vision impairment, there is virtually no literature. More importantly, work on assistive technology in the developing world has emerged only in the last few years following the UN Convention on the Rights of Persons with Disabilities. In this period, there has been some development of low-cost tools related to vision impairment, and studies of technology adoption on issues such as cultural concerns around assistive technology donations.

1.7 Use of Technology in the Classroom

Using technology in the classroom engages and stimulates the students and allows them to learn more independently. Students themselves report the positive effects of technology in the classroom, and educators notice that the participation level changes when computers are used (Godzicki, Godzicki, Krofel, & Michaels, 2013). Using SMART Boards, laptops, and other technologies supports collaboration, creativity, and further engagement, even outside the classroom (Downes and Bishop 2012). A great deal of work has been done regarding classroom engagement through technology, especially for STEM areas, and this has been often studied with students without specific disabilities (Center for the Study of Mathematics Curriculum 2012). One middle school explored using newer technology (iPod Touch) in and outside the class environment to support traditional learning within the classroom. By mimicking the real world (through the use of a mobile device) and providing additional content to supplement the traditional material, the aim was to engage the students more fully. The alternate method of information presentation, through the use of technology, succeeded in supplementing the students' experience and gave them more independence in learning (Franklin & Peng, 2008). Another program deployed within classrooms was Math Insight, which included computer tools for performing common math functions (e.g., graphs, data tables, geometric sketching). Both teachers and students reported the system was valuable to the class environment and it increased the students' engagement and involvement (Zucker, 2006). As technology becomes more integrated into classrooms, assistive technologies (any device or system that "improves functional capabilities of a child with a disability" could presumably serve as a way to support education for students with vision impairments (U.S. Department of Education 2004; Assistive Technology Partnership 2008). Assistive technology could benefit students and found that fewer than half of the students who could benefit from these technologies use it at school (Kelly, 2009). Further, the students who most frequently use assistive or educational technologies in the classroom are those who do not attend local schools (Kelly, 2009). Surveys about the use of assistive technology in the classroom report that a majority of teachers do not have training on how to use them effectively in the classroom (Abner and Lahm 2002).

1.8 STEM Education for Visually Impaired

Blindness is generally the most dreaded disability worldwide invokes societal sanctioning for those belonging to this group (Dickerson, Smith, & Moore, 1997). This is to the extent that human attitudes compound the negative effects of physical barriers to the education of blind and partially sighted learners (Fraser & Maguvhe, 2008). The absence of accessible media for the presentation of concepts in fields of study with a large amount of complex visual information - such as mathematics, engineering, physics, chemistry, and biology - has traditionally been highlighted as a legitimate reason to conceal these areas of learning from large-scale entry and pursuance by the blind and partially sighted learners (Cryer et al., 2013) ; (Schleppenbach, 1996).

Due to impairment in vision, learners with blindness and low vision often lack contexts, opportunities and have participation restrictions in science, technology, engineering, and mathematics (STEM) education. Many argue that STEM education depends on sight-based instruction and visual learning techniques hence learners with visual impairment (VI) cannot benefit from such education. STEM education plays a critical role in the development of modern industries, research, and development. It enriches the learning process by raising curiosity, enhancing creativity, sharpening entrepreneurial skills, driving innovation, and developing problem-solving skills which further help in solving problems in real-life situations and retention of jobs. Unlike teaching the subjects like science and math's individually, the STEM educational approach advocates interdisciplinary learning through an integrated approach (Pagar, 2018). STEM education helps in the creation of new job opportunities for learners in today's industrial era.

A lack of accessible media for teaching the abstract concepts and visual resources (graphs, diagrams, charts) involved in STEM education among learners with VI, thereby limiting the foray of learners with visual impairment in the field of STEM education. The study further highlighted the challenges posed by 'accessing technical notations - equations and formulae in Braille', a difficulty for learners with visual challenges to involve in certain lab experiments, and heavy reliance on the 'chalk-and-talk' method by educators of STEM (Cryer et al., 2013).

1.9 Science Education for the Blind

Science learning should be accessible by all learners including students with special educational needs (Holbrook, 2010). (Atika, Ediyanto, & Kawai, 2018) (Atika et al., 2018). Science Education for All is one of the manifestations of Education for All (EFA). A student with visually impaired is one of the types of students with Special Educational Needs who have limitations to obtain information through their eyesight sense. Besides being accessible to all learners, science learning also should be prepared for further education, employment, and independent living (Individual with Disabilities Education Act (IDEA)) and should help students in developing an understanding and habits of thinking, which is needed to solve the problems in life for students who have Visual Impairment (Mundilarto, 2002).

The learning of science, highly challenging for pupils with visual impairment due to the presence of abstract concepts and dependence on visual modes of learning and instruction in general schools which limit their participation and learning due to lack of visual input for such learners. The study further states that adaptation of apparatus and learning technologies increase the access of learners with blindness towards STEM subjects and they have been observed to participate competitively irrespective of their handicap, thus suggesting that psychological barriers are overcome through accessible learning technologies (Sahin & Yorek, 2009)

The areas of science and mathematics have traditionally been inaccessible to students with visual impairments. Complex and high-tech fields such as Chemistry, Physics, Engineering, Biology, and Mathematics are rife with visually-presented concepts and information. Historically, this complex visual information has not been made available for widespread use in a format easily accessible to blind and students with visual impairment. This lack of information, in turn, leads to decreased interest in scientific fields by the blind, and thus few visually impaired scientists exist to provide standards for imparting scientific knowledge to the blind and to serve as mentors and role models for those students with visual impairment who wish to pursue careers in the sciences (Schleppenbach, 1996).

Willings (n.d.) mentions the need for classroom practices like self-contained classrooms acting as science teaching stations or resource rooms having pets, plants, etc which will allow young learners with visual challenges to be fully included in science experiments at the primary and pre-primary stages. Collaborative teaching techniques can allow easy adaptations of curriculum, materials, models, and charts for all subjects at the beginning of the session; exploratory learning through tactile sense should be encouraged for such learners like stroking of pets, feeling textures of leaves, plants, flowers, stones, etc.; usage of adaptive tools like magnifiers, prismatic glasses, Braille slates, and geometric kits will ensure greater participation of the target group.

1.10 Importance of Mathematics Education

Mathematics cultivates thinking and reasoning skills. It lays the foundation for systematic thinking through the numerical and spatial aspects of the objects (Agrawal, 2004). As a subject, Mathematics plays an important role in society and the school curriculum is formulated in such a way that Mathematics is given a central and significant place in it. Teaching and learning Mathematics is compulsory right from the primary level to the secondary level of education.

Mathematics is a field that has often been considered beyond the capacity of the blind to master. Traditionally it has been inaccessible to visually impaired and blind students because its content is rich with visually presented concepts and information (Schleppenbach, 1996). Indeed, the concepts of Geometry do not come readily to a blind person, because of its spatial content. Yet there is no overwhelming reason why a person of sufficient ability should fail to become a successful mathematician simply because he or she is blind (G. Jackson, 1968).

According to Hudoyo in Supardi, mathematics is a matter of ideas, structures, and relationships arranged in a logical sequence (Supardi, 2012). Thus, mathematics deals with abstract concepts developed for logical reasons, to prove a statement, true or false. Meanwhile, according to Sumarmo in Tapantoko, mathematical learning is directed to develop mathematical thinking ability, which includes comprehension, problem-solving, reasoning, communication, mathematical correction, critical and objective attitude (Tapantoko, 2011).

Mathematics education aims to study the factors that influence the learning of mathematics and to develop programs to improve the teaching of mathematics. It fits the opinion of Godino & Batanero "Mathematics education is aimed to study the factors affecting the teaching and learning of mathematics and to develop programs to improve the teaching of mathematics" (Godino, Batanero, & Font, 2007).

The National Council of Teachers of Mathematics (NCTM) establishes five standards of mathematical ability that students must possess namely problem-solving skills, communication skills, connection capabilities, reasoning, and representation (National Council of Teachers of Mathematics (NCTM), 2000). The application of mathematics learning is very useful in everyday human activities, such as in the activities of buying and selling transactions, measuring, calculating the distance, and so forth (Herwanto, 2013). According to Mensah Mathematics is necessary for our daily lives, regardless of our educational Assistive Technology in Mathematics Learning background or social status (Mensah, 2017). The benefits of mathematics are not just limited to knowledge in computing, but more importantly, when every individual can master mathematics well, then their thinking patterns are more rational and critical. Hadjichristou also explained that Mathematics is communicated through language, and thought is the communicated language (Hadjichristou, 2007). This analogy shows us that mathematics is a way of thinking. Mathematics helps people to create and solve problems by thinking objectively, independently, and confidently in explaining relationships. Thus, these facts make mathematics education very important in all educational systems.

1.11 Technology and Use of Technology in Teaching Subjects for Blind Students

Computer interfaced instrumentation provides tools for mass-volume measurements, and talking calculators facilitate calculations (Van Wagner, 1994). Qualitative identifications of certain non-hazardous materials could be made using the sense of smell (Keller Jr, 1981). Chemical reactions involving colors can be identified using a colorimeter interfaced with a computer programmed to convert color signals into Braille outputs. Also, light probes interfaced with Braille computers can be used as detectors for determining end-points in volumetric analyses. Similarly, modified ultra-violet and infrared spectrophotometers can be used for chemical characterization. "Biology". Tactile modifications of preserved specimens and humanely prepared living organisms (e. g., live Cray fish with rubber tubing carefully placed over their pincers) could form excellent hands-on specimens in biology (Malone & De Lucchi, 1979).

Modifying chromosome kits with "pop-it beads" using readily available tactile markers for teaching cell division was suggested. The suggested tactile markers include small plastic strips of various sizes and shapes to represent Colour codes and holes to represent relative positions of chromosomes (Ricker & Rodgers, 1981). (Abruscato, 1988) recommended the following activity to enable students with visual impairments to observe fish in an aquarium: Place inside the aquarium a slightly smaller plastic aquarium with drilled-in holes which function as a sieve. As the student slowly lifts the inner aquarium and drains off the water into the larger aquarium, the fish will be trapped in the bottom of the inner aquarium. Now by the sense of touch, the student can explore the fish. Supervision might be required to make sure fish are properly handled.

The preponderance of visually oriented and visually complex concepts and information in science classrooms poses significant challenges to learning among students with visual impairment. Without systematic instructional attention to these challenges, science may seem inaccessible to many students with visual impairments. Unfortunately, (Stefanich, Norman, & Egelston-Dodd, 1996) found that most science teachers and college science educators have little or no direct experience in teaching disabled students and often hold stereotypical views of what students with disabilities can and cannot do.

The mathematics curriculum in elementary schools includes conceptual understanding, procedural fluency, and strategic competence in terms of mathematical proficiency (Kilpatrick et al.2001). First, conceptual understanding refers to students' comprehension of mathematical concepts and the relationships between concepts. Various computer-based scaffolds and feedback to build students' concepts and clarify potential misconceptions. For guiding students' discovery of the patterns of concepts, (Yang, Cheng, Ching, & Chan, 2012) adopted an inductive discovery learning approach to design online learning materials in which students were provided with similar examples with a critical attribute of the concept varied. (McLaren, Adams, Mayer, & Forlizzi, 2017) provided students with prompts to correct their common misconceptions about decimals. They conducted a study with the game adopted as a replacement for seven lessons of regular mathematics classes. They found that the educational game could facilitate better learning performance and enjoyment than a conventional instructional approach.

Assistive technology can be items, tools, or products made by teachers, designed to improve students' functional abilities. This is per the opinion of Akpan& Beard "Assistive Technology can be any item, piece of equipment, or teacher-made product that is designed to improve a student's functional capability" (Akpan & Beard, 2014). The National Assistive Technology Research Institute (NATRI) at the University of Kentucky examined the use of assistive technology in 10 US states in 2005 and found that assistive technology was more used by students with disabilities such as autism, hearing loss, or visual impairment than students with learning disabilities (Hasselbring & Bausch, 2005).

Assistive technology is one of the factors that determine the high understanding of students with visual impairment in math lessons. The intrinsic factors that affect the level of understanding of students with visual impairment' math are a. The physical condition of students with visual impairment b. Students' intelligence c. Lack of stimulus and motivation d. Psychological factors of the students before the learning begins e. The cause and time of the visual impairment. While extrinsic factors that influence the level of students' mathematical understanding include: a. inadequate class conditions b. Lack of media or assistive technology that teachers use in mathematics learning. c. The existence of the teacher d. The material being taught. With the development of science and technology, assistive technology for Children with visual impairment has also been developed and many pieces of research have been developed, such as Herwanto's study entitled "Improving Mathematics Learning Achievement of Multiplication through Abacus Media for Students with visual impairment" resulted that Abacus can improve mathematics learning achievement for students with visual impairment (Herwanto, 2013). Abacus is a calculating tool consisting of beads that have certain values, ranging from units, tens, hundreds, thousands, and so on. Abacus is a quite practical tool to be used not only by students but also can be used by students with visual impairment through modification (Herwanto, 2013).

The study on "Development of Audio-Based Mathematical Learning Tools On Circumference and Area of Triangle for Students with visual impairment at SMPLB TPA Jember" was conducted using mathematical tools equipped with audio to facilitate students with visual impairment in learning mathematics with the subject of circumference and area of a triangle (Primasyah, 2013).

Research conducted by Windasari under the title "Interactive Media Learning Design of Full-Audio CD and Mathematical Learning Aids for Building Curved-face threedimensional objects for Elementary High School Students Exceptionally Sightless (SMPLB-A) ". The assistive technology developed for students with visual impairment is fully interactive CD audio for the visually impaired in learning curved-face three-dimensional objects mathematics material (Windasari, 2011).

Nurajab modifies the domino game method by adding braille letters to improve the ability of addition and subtraction in mathematics learning It is found that the modified game can help to improve the ability of the addition and subtraction of students with visual impairment in learning mathematics.

Karnali developed a braille monopoly media in the material of mixed rational numbers for visually impaired learners (Karnadi, 2016). Tufani made modifications to the geoboard equipped with audio to help children with visual impairment in learning two-dimensional figures material (Tufani, 2017). The tool, once tested, proved to be effective in assisting the students with visual impairment in understanding the circumference of two-dimensional figures material.

Optical Character Recognition (OCR) and Descriptive Video Services (DVS) are technologies that can be used to help students with visual impairment in learning mathematics by scanning material through Optical Character Recognition (OCR) that can scan and read printed texts, enabling them with visual impairments to access all types of printed materials and enabling them to read the material independently.

The scanned material can be read using Descriptive Video Services (DVS) commonly called screen reader which allows the computer to read all the data on the computer orally (Hasselbring & Glaser, 2000). View Plus Accessible Graphing Calculator is an assistive technology that enables the visually impaired to be able to read graphics through audio. In addition, there are also MathTalk applications that can help students with visual impairment translate mathematical problems into Braille. Select Math Program with Boston Public Schools is a website that provides access to learn math and it has been adapted for children with visual impairment (Akpan & Beard, 2014). From various researches on assistive technology in mathematics learning, almost all of them develop various technologies that can optimize the sensory capabilities that are still owned by the visually impaired such as touch, smell, and others in studying mathematics subjects. This is because the Children with visual impairment's condition is abnormal in their visual, so assistive technology is directed to optimize their other still functioning senses. The technology seeks to help students to be easier to understand the material at the disequilibrium stage. If the students can pass the stage well, then it will be easier for them to do the thinking process in solving mathematical problems in the next stage (Lesmana, Susanto, & Oktavianingtyas, 2017). Assistive technology is also directed to facilitate students with visual impairment in learning certain materials that are difficult to learn, broaden their understanding of the concepts and reduce some difficulties encountered when doing mathematical problems.

In the last 30 years, the technology boom has produced an abundance of tools to assist with learning and teaching, including those useful to teachers of students who are visually impaired. However, facilitating the study of mathematics for students who are visually impaired (that is, those who are blind or have low vision), specifically Braille readers, requires that teachers sift through a growing number of continuously evolving products. High-tech assistive technology includes stand-alone devices such as talking calculators, computer hardware, and the software used within electronic devices. Often, itinerant teachers 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). 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. For a classroom teacher who has a visually impaired student, the presence of technology in the classroom is not optional but necessary.

Many mathematicians, such as (Buteau, Marshall, Jarvis, & Lavicza, 2010) now 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 who are visually impaired must have access to technology that provides these same supports.

(Schweikhardt, 2000) noted that requirements for the successful integration of students who are visually impaired 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. Numerous projects that focus on the ability to concurrently communicate in braille and print-Math Genie and Lambda systems, for example-incorporate innovations such as the MathML sublanguage, MathType software, audio output, and speech recognition, and are in development around the world (Pontelli, Karshmer, & Gupta, 2009).

Digital-based learning and technology are important tools in mathematics education (Li & Ma, 2010). The role of educational technology in teaching strategies has led to the increased use of technology and media-rich learning environments (National Council of Supervisors of Mathematics [NCSM] & Consortium for School Networking [CoSN], 2015). In addition, people’s expectations in the learning environment are changing with advances in digital technology. Many students today are offered computers equipped with increasingly sophisticated software, graphics calculators, hand-held devices with integrated graphics packages with dynamic geometry software, and web-based applications offering virtual learning (Kleanthous & Meletiou-Mavrotheris, 2018) ; (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014).

The new educational landscape has a great potential to empower students to increase their learning. Assistive technology has become a tool for mathematics exploration and learning in a range of curriculum topics. Some programmes may cover many areas of mathematics, while others are designed to allow for in-depth probing of only one area (Asebriy, Raghay, & Bencharef, 2018) 'Microworld program' creates specific constructivist environments and is aimed at a limited set of mathematics ideas (Sinclair & Jackiw, 2004). The programmes are 'filled with content' that can be configured to suit a wide range of learning modes, from guiding the student step-by-step to more open-ended explorations. 'Guided tasks' are most often used by the youngest students to acquire specific mathematical skills and competence. The emergence of technologies of broader mathematical expressivity managed to affect a range of curriculum topics (Sinclair & Jackiw,2004). Digital tools that are 'empty of content', such as spreadsheets, graph software, and computer algebra systems (CAS), are technologies that are only loosely coupled to specific curricular contexts but are suitable for mathematical explorations. These tools are often used by students in lower and upper secondary schools. An increasing trend in mathematics education in lower and upper secondary schools is that teachers make short instructional videos on given topics, which the students study at home. This 'flipped classroom' is an instructional strategy that reverses the traditional learning environment by delivering instructional content outside the classroom. In a flipped classroom, students watch lectures online and collaborate in online discussions. In this way, learning is understood as including a social dynamic rather than being a solely individual learning process (Moore, 2016).

The development towards the increased use of digital learning opportunities is challenging for students with visual impairments (VI) and their teachers (Asebriy et al., 2018) ; (Ashraf, Hasan, Lewis, Hasan, & Ray, 2016). Therefore, it is relevant to gain more knowledge about how students with vision loss can follow the teaching in mathematics and succeed in learning their age-related curricula (Besnoy, Manning, & Karnes, 2005; (Ferrell, 2011; Klingenberg,2013). In mathematics, physical textbooks are often replaced with digital textbooks, and the teaching materials are presented or read on a computer or similar device. (ANDERSON-INMAN & Horney, 2007) define digital text (e-text) as textual materials presented electronically or digitally. Supported e-text is defined as digital text that is modified or enhanced in ways that are designed to increase comprehension and promote content area learning. Supported e-text allows digital text to be reproduced in a medium such as synthetic speech, human-voice audio recordings, video, large print books, and Braille. Braille is a tactile writing system designed for use by people who are severely visually impaired (Augestad, Klingenberg, & Fosse,2012). The different types of mathematical Braille codes create problems in the production of relevant software and hardware about the universality of mathematics. Braille is traditionally written in the form of embossed paper, but written language can also be provided through an electronic Braille display. Screen readers (e.g., Job Access With Speech, JAWS) are software applications that convert materials displayed on screen into speech synthesizer or Braille (Asebriy et al., 2018) ; (Stefano, Borsci, & Stamerra, 2010). The advantages of refreshable Braille displays over synthetic speech are that it provides direct access to information; allows the user to check the format, spacing, and spelling in the text; and is quiet (R. M. Jackson, 2012). In addition, Braille displays allow for notetaking and file storage.

Furthermore, students with visual impairment may connect a personal digital assistant (PDA) to a computer and use it as a Braille display or speech synthesizer (Ernst, Swan, Cheung, & Girouard, 2017). Students with visual impairments can supplement their reading of Braille or printed text with aural outputs from screen readers or digital talking books (Argyropoulos, Paveli, &Nikolaraizi, 2019). For example, DAISY (digital accessible information system) books have been developed to assist people with VI in the learning process (Maćkowski, Brzoza, & Spinczyk,2018). Supplementation with speech has been considered a necessary tool for increasing access to information because Braille and large print materials have not always been available when needed (R. M. Jackson, 2012).

The subject that is difficult to learn by Children with visual impairment in mathematics (Diyansyah, 2017). In learning mathematics, Children with visual impairment have difficulty understanding the mathematical symbols. It also affects the difficulty in performing arithmetic operations that exist in mathematics subjects. Mathematics is an important subject to be learned by children because it is useful for everyday life activities such as in the sale, purchase, measurement, and other activities. In the era of science and technology, Children with visual impairment need to understand the basics of mathematics to play a role in society well (Sánchez & Flores, 2005). Therefore, Children with visual impairment need help to overcome these obstacles so that children can learn independently (McCarthy & Shevlin, 2017); (Justicia, Tolle, & Amalia, 2017). One solution to overcome this problem is by utilizing the development of the technology called assistive technology. Assistive technology is one of the efforts to help children with visual impairment in learning mathematics. The technology is designed with customized capabilities possessed by children so that children will be easier in following the learning, especially on learning mathematics. With the development of science and technology, a lot of assistive technology has been developed to meet the learning needs of Children with visual impairment. The development of assistive technology is growing rapidly; many studies have been done by experts (Wiazowski, 2009).

Other computer programs have undergone testing which may provide partial solutions to the lack of tools and programs available for mathematics education of students with visual impairment. The conclusions based on these studies suggest that audio features, in general, are more effective than Braille text, although some studies noted in feedback from participants that providing Braille text in addition to auditory speech could be useful (Beal, Rosenblum, & Smith,2011). In addition, if hints are available throughout a problem, student involvement and motivation are more likely to be maintained (Beal & Rosenblum,2018). However, a hint being provided is not the most notable feature of tested technology, as these programs were primarily tested on lower-level mathematic subjects where teachers were available in residential classrooms to assist students when necessary.

The literature suggests a note-worthy potential for tablet and technology-based tools as students are shown to be more encouraged and focused when using such programs compared to solely Braille-based methods of instruction (Beal & Rosenblum,2018). This technology also assists in the visualization of graphs, figures, and other highly visual components of mathematical instruction.

Geometry is one area of mathematics for teaching about lines, line segments, rays, angles, and geometric shapes. The contents are developed to learn how to measure lengths of lines, angles, perimeters, and areas of 2D shapes. The volumes and surface areas of 3D shapes can be calculated using geometry concepts. Almost (Nachaphan

Junthong, Suchapa Netpradit, and Surapon Boonlue) all geometry problems require a drawing that cannot be used on a Braille typewriter.

Blind students about their interpretation of two-dimensional shapes according to their thinking were interviewed. They explained that “the visual experience of a blind student with total blindness from birth has an important role in the way s/he illustrates or describes a two-dimensional shape. The shape and the length of the subject line are explored by using tactual ability through its sense of touch.” (Budayasa & Juniati, 2018).

The new adapted teaching strategy developed applied orientation and mobility programme gave access to learners with visual impairment to participate in geometry and it enhanced task performance of the learners in geometry (Jurmang, 2015).

Recently, 3D printing technology is one of the most advantageous technologies for inventions, when compared to the traditional manufacturing methods (Tractus3D, 2019) because of the high level of accuracy and the ability to make decisions that reduce cost, time, and errors.

Geometry is a material that combines the concept of geometry with the development of visual perception (Barmby, Bilsborough, Harries, & Higgins, 2009). This material is considered an important thing to be taught because it may raise people’s ability to solve some daily problems. Hoffer (Yee, 2009) said learning geometry can develop various abilities such as visual skill, verbal skill, drawing skill, logical skill, and applied skill. However, this material should be mastered by students, not only in mathematics lessons but also in daily life. In general, geometry is taught with various examples of visuals and illustrations (Rouzier, Hennion, Segovia, & Chêne, 2004). Vision limitation of the visually impaired makes them can’t learn to geometry as easily as other students who can access visual data. Geometry demands the teacher to learn perception. Limitation of visually impaired demands the teacher must have maximizing the senses of touch. The sense of touch is used to identify the geometric shapes. It is very good to increase the understanding of the visually impaired student (Salisbury, 2007). That effort can be done by the provision of props. Mani, et. al (2005) said that should geometry props have well-proportioned, strong, and secure.

While (Suherman, 2003) said props should be durable, interesting, a measure proportionate, multi-function, and can be presenting the concept. Technology is a means that makes work or tasks easy, efficient, and operative. A more encompassing definition refers to it “as the tools created by human knowledge of how to combine resources to produce desired products, to solve problems, fulfill needs, or satisfy wants.” (Koehler & Mishra, 2008).

In mathematics, “technology influences the mathematics that is taught and enhances students’ learning.” (Kastberg & Leatham, 2005). With Algebra 1, where students’ thinking develops from concrete to abstract, technology plays an essential role that facilitates this cognitive transformation. A vital part, which helps students understand the “theories for the solution of equations, finding values of the unknown quantities, or the conditions under which they can or cannot be found” in Algebra. (Bunch, 2009).

Graph literacy is an important skill to master for a variety of reasons, for instance, to pursue a career in science, technology, engineering, or mathematics (STEM), but the problem with graphs is that they are visual in nature. Auditory graphing systems that use sound to convey information are a strategy for addressing this issue. Auditory graphs are capable of delivering graphing information in real-time, are easy to customize, more portable, and, as a teaching medium, can be accessed by low-vision, blind, or sighted users.

Auditory graphing systems use sonification (nonspeech audio) to convey information about data (Kramer et al., 1999). They can provide an alternative medium for data analysis of both simple and multidimensional data, and have utility for any user regardless of ability to see visual plots and graphs (Nees & Walker, 2006) (Fitch & Kramer, 1994). There have been many studies that demonstrate that auditory graphs can present data in a meaningful way such that a user can perform various mathematical functions. For instance, research has shown that auditory graphing systems can be used to find patterns, conduct point estimation, provide context, and show error and uncertainty (Mansur, Blattner, & Joy, 1985 (D. R. Smith & Walker, 2002) (Batterman & Walker, 2012). Using sound and sonification can be a very effective way to explore and interact with data, and are often used as a category of AT for users with vision impairment.

Other early systems have demonstrated that people with vision impairment can access information from sonified line graphs with different types of data series (Brown, Brewster, Ramloll, Yu, & Riedel, 2002). The success and potential of using sound-mappings to display data have led to the creation of some software packages built with auditory graphing in mind [NASA Information Access Lab, 2004, (Gardner, 1999). These applications, while a good first step toward accessible graphing systems, have not been studied in a learning environment and are typically only used after graphing concepts are already learned rather than as a tool to teach graph principles.

Employing auditory graphs in classrooms is a promising solution to aiding students with vision impairment to learn graphing principles not only because of the reasons listed above but also because they require no additional specialized equipment or assistive technology to use. Additionally, there is some evidence that presenting information using multiple representatives can enable students to customize their learning experience and improve understanding and transfer (Upson, 2001), (Bjork & Richardson-Klavehn,1989).

Graphs are forms of imagery that students encounter in many disciplines associated with the physical sciences ((Beichner, 1994) ; (Hoban, Finlayson, & Nolan, 2013) ; (Potgieter, Harding, & Engelbrecht,2008), human sciences (Carpenter & Shah, 1998) ; (Shah & Carpenter, 1995) ; (Shah & Freedman,2011) and history (Guthrie, Weber, & Kimmerly,1993). Graphs are of particular importance in science, technology, engineering, and mathematics (STEM) (Asiala, Cottrill, Dubinsky, & Schwingendorf,1997) ; (Friel, Curcio, & Bright,2001) ; Leinhardt, Zoslavsky, & Stein, 1990). A large portion of the content in every STEM discipline is communicated through words and images that make use of vision (Moon, Todd, Morton, & Ivey, 2012). According to Cleveland, McGill, and McGill (1988) and Pinker (1990), humans attend more closely to graphs than they do to alternate forms of visual representation.

Pinker, along with Cleveland et al., stressed that using graphs requires the process of relating variables to each other, and individuals start that process by grouping a graph’s components based on location and similarity of components, regardless of the type of graphs they use. For students to succeed in any given area of STEM, students must learn how to relate variables to one another through the use of graphs (Beichner, 1994); (Hoban et al., 2013); (Potgieter et al.,2008).

Coordinate graphs and number lines are an essential part of mathematics education and are often part of required standards from kindergarten to high school (Georgia Department of Education, 2012). Graphs are also important for interpreting trends and patterns in data and comparing two datasets when other statistical properties such as mean and variance are largely similar (Anscombe, 1973). Competency in mathematics, including graph literacy, is key to success in science, technology, engineering, and mathematics (STEM) fields (Carnevale, Smith, & Melton, 2011). However, since graphs and number lines are typically taught and displayed visually, students who have vision impairment are often at a disadvantage when learning STEM material or trying to complete homework.

Touch-based assistive technologies are potential tools to provide graphical content to students who are blind and improved their learning possibilities and social inclusion. Students who read Braille and have access to refreshable Braille displays in mathematics can receive training in using spreadsheets or similar programmes. The students learn to type text, numbers, and formulae in the cells but are dependent on assistance to interpret the results when they are presented as graphs and columns. In other words, there is a need for tools to display graphics representations for students with visual impairment.

Mathematics education is traditionally visual, since graphs, equations, and number lines inherently present their information in a visual-spatial manner; however, for students with vision impairment, math can be difficult to learn since there has been a distinct lack of alternative teaching methods. Interacting with and understanding graphs is one of the core skills necessary for more advanced math classes such as Geometry, Trigonometry, and Calculus. Further, low vision and blind students are at a disadvantage in other STEM classes, for which math (and especially graphs) is a critical foundation. Currently, simple graphing concepts are taught to students with visual impairment through tactile graphs; while this works for the basics, it does not help the students understand all the necessary graphing concepts (Davison, 2013).

Auditory graphs (using sound attributes such as pitch to represent the numerical value) present an alternative to visual graphs. Flowers found that key information from graphs can be linked to sonifications (non-speech sounds) to denote features of the graph and changes in graph values (Flowers, 2005). Math sonifications have been used to help present numerical and graphical data through different methods, including as part of a haptic system, as a game, and even as a supplementary tool for students without visual impairment (Van Scoy, McLaughlin, & Fullmer, 2005) ; Hetzler&Tardiff, 2006; (Upson, 2001) (Upson,2002).

Auditory graphs and sonifications (non-speech sounds that convey information) can successfully portray key information from graphs through their use of sound (Flowers, 2005). They can provide an alternative medium for data analysis of both simple and multidimensional data, and have utility for any user regardless of ability to see visual plots and graphs (Fitch & Kramer, 1994) ; (Nees & Walker, 2006). Auditory graphing systems can be used to find patterns, conduct point estimation, provide context, and show error and uncertainty (D. R. Smith & Walker, 2002) ; (D. R. Smith & Walker, 2005) ; (Batterman & Walker, 2012) Using sound and sonification can be a very effective way to explore and interact with data. Other studies found that using software with sonifications led to greater engagement with learning Cartesian graphing concepts (Upson, 2001) (Upson, 2002).

Auditory graphing systems (that use sounds to convey information) are one type of assistive technology used to supplement math education to improve graph literacy for individuals with vision impairment. Auditory graphs are capable of delivering graphing information in real-time, are easy to customize, are more portable, and, as a teaching medium, can be accessed by low-vision, blind, or sighted users. One such tool is the Graph and Number line Input and Exploration software.

Auditory graphing systems are not a new concept. One of the earliest uses of an auditory system for exploring graphs was the prototype “sound graph” developed by (Mansur et al., 1985). This system is used to pitch to map two-dimensional line graphs. Subjects were tested on their ability to determine mathematical concepts such as the slope of a line, symmetry, and identification of straight lines versus exponentials. These results were compared to results from completing similar problems using tactile graphics. Sound graph compared favourably to tactile graphs in terms of accuracy but performed better in terms of speed. Authors also argue that it is more cost-effective to produce and provides more flexibility and greater independence for persons with vision impairment.

Auditory graphing systems used by blind students began with the prototype “sound graph” (Mansur et al., 1985). This system is used to pitch to map two-dimensional line graphs. Sound graph compared favourably to tactile graphs in terms of accuracy but performed better in terms of speed. Auditory graphs provide more flexibility for data representation and greater independence for persons with vision impairment since they directly controlled their interaction with the graphs.

1.12 Rationale for the Study

Mathematics education is easily accessible to fully sighted children and it is less accessible to students with vision 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, Lauwers, Dewey, Stepleton, & Dias, 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 impairments 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 Children 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 Children 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). Children who are visually impaired should learn mathematical skills at the same level as their sighted peers (Tindell, 2006).

Students do not have the skills necessary to start understanding algebraic functions and graphical representations until they enter high school (Capraro & Joffrion,2006). In many Algebra courses, teachers introduce algebraic functions in numeric form and their corresponding graphs (Aspinwall, 2002; Ellis, 2007, 2011; Even, 1998; Knuth, 2000; Leinhardt et al., 1990; Oehrtman, Carlson, & Thompson, 1997).

These researchers assert that students must begin the journey of understanding graphical representations by learning how to use them in a mathematical context before they attempt to use graphs in the sciences, where content oftentimes builds upon concepts discussed in mathematics courses.

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 consume 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 who are visually impaired. 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 et al.,2011). For a classroom teacher who has a visually impaired student, the presence of technology in the classroom is not optional but necessary. Many mathematicians, such as (Buteau et al., 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 who are visually impaired must have access to technology that provides these same supports.

Students with visual impairment use technologies that take advantage of touch (American Thermoform, 2016; (Printers, 2016), sound (Ben-Tal, Berger, Cook, Daniels, & Scavone, 2002) ; (Davison, 2013), and language (natural language assistive technologies, NLAT), (e.g., tools that produce textual descriptions of graphical representations) (Demir et al.,2010) ; (Ferres, Parush, Roberts, & Lindgaard, 2006).

The most common approach students with visual impairment use to access graphical information is through touch, but these technologies are costly and oftentimes require the use of someone with vision to construct the graphic ((Ferres et al.,2006) ; Gerenazzo, Brayda, Bedin, Campus, &Avenzini, 2016). While tools used to relay graphical information through sound are downloadable and free of charge, Millar (1994), along with Gerenazzo et al. recommends that students refrain from using these tools until they have gained sufficient experience with tactile graphics. Similar to software that allows for graphs to be accessed through sound, software that allows for access through textual descriptions is downloadable and free of charge.

Computer-based accommodations have become increasingly common not only for STEM education but within the entirety of education, across all fields and at all levels. Information technologies may function as accommodations themselves, or they may serve as assistive technologies to render computers accessible to users with disabilities. As (Fichten et al., 2004) point out, personal computers now play a part in the entire educational experience, inside and outside the classroom, throughout K-12 education and persisting through university study. That said, the potential of the computer to enhance the learning experience may be offset by several factors, such as problems of implementation by untrained or inexperienced teachers (Fichten et al., 2009).

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 focussed to develop Computer Assisted Cartesian Plane to enhance 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 student's participation and performance in plotting and *Finding Points* in this Experimental study.

1.13 Statement of the Problem

The statement of the problem is worded as: **"Developing Computer Assisted Cartesian Plane to Enhance Graph Skills of Students with Visual Impairment"**

1.14 Terms Used in the Study

Cartesian Plane

A Cartesian coordinate system in a plane is a coordinate system that specifies each point uniquely by a pair of numerical coordinates, which are the signed distances to the point from two fixed perpendicular oriented lines, measured in the same unit of length. Each reference line is called a coordinate axis or just axis (plural axes) of the system and the point where they meet is its origin, at ordered pair (0, 0). The coordinates can also be defined as the positions of the perpendicular projections of the point onto the two axes, expressed as signed distances from the origin.

- Wikipedia

Quadrants

The axes of a two-dimensional Cartesian system divide the plane into four infinite regions, called **quadrants**, each bounded by two half-axes. These are often numbered from 1st to 4th and denoted by Roman numerals: I (where the signs of the (x; y) coordinates are I (+; +), II (−; +), III (−; −), and IV (+; −). When the axes are drawn according to the mathematical custom, the numbering goes counter- clockwise starting from the upper right ("northeast") quadrant.

-Wikipedia

Axes

In the Cartesian Plane, there are two axes. One is the horizontal axis, called the axis and the other is a vertical axis, which is called the y-axis.

Origin

The point where the axes of a coordinate system intersect. The point where all coordinates are zero.

Coordinates

Coordinates are a set of two values that locate a specific point on a coordinate plane grid, better known as a coordinate plane. A point in a coordinate plane is named by its ordered pair (x, y), written in parentheses, corresponding to the x-coordinate and the y-coordinate. These coordinates can be positive, zero, or negative, depending on the location of the point in the respective quadrants.

Graph Skills

Graph skills are the term used to represent the skills needed in graphs viz *Plotting and Finding points* on the Cartesian Plane.

Total Vision Impairment / Total Blindness

Total Blindness is a term used to describe those who have complete lack of light perception, documented as no light perception (NLP). Only about 15% of people with eye disorders have total blindness, the majority of those with visual impairment have some level of vision.

Tactile Cartesian Plane

A Tactile Cartesian Plane is a representation of a tactile graph sheet designed in a manner that is most meaningful to the reader by providing clearer information regarding Axes, origin, and Gridlines.

Computer Assisted Cartesian Plane

Computer Assisted Cartesian Plane in this study denotes a software system developed using visual basic language with the features of *Plotting points* and *Finding points* on the Cartesian Plane with a minimal number of keys usage.

Inclusive Education

A system of education wherein students with and without disability learn together and the system of teaching and learning is suitably adapted to meet the learning needs of different types of students with disabilities.

- Rights of Persons with Disabilities (RPWD) Act, 2016

Voice Message

Voice messaging is an instant communication technology in which messages are transmitted via voice media. Voice messaging is an alternative to text messages.

- Techopedia

1.15 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 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.

1.16 Hypotheses

The following null hypotheses were framed for the study

1. There is no significant difference in the level of acquisition of Concepts of Cartesian Plane among students with visual impairment before and after the intervention.
2. There is no significant difference in the mean scores of *Plotting Points* and *Finding Points* on Quadrants and Axes with respect to Tactile Cartesian Plane before and after intervention.

3. There is no significant difference in the mean scores of *Plotting Points* and *Finding Points* on Quadrants and Axes with respect to Tactile Cartesian Plane used in Pretest and Computer Assisted Cartesian Plane.
4. There is no significant difference in the mean scores of *Plotting Points* and *Finding Points* on Quadrants and Axes with respect to Tactile Cartesian Plane used in Posttest and Computer Assisted Cartesian Plane.
5. There is no significant difference in the mean scores of *Plotting Points* on Quadrants and Axes while using Tactile Cartesian Plane in Pretest & Posttest and Computer assisted Cartesian Plane.
6. There is no significant difference in the mean scores of *Finding Points* on Quadrants and Axes while using Tactile Cartesian Plane in Pretest &Posttest and Computer assisted Cartesian Plane.
7. There is no significance difference within the mean difference scores of Concepts of Cartesian Plane while using Tactile Cartesian Plane in Pretest & Posttest and Computer Assisted Cartesian Plane.
8. There is no significance difference within the mean difference scores of *Plotting Points* on Quadrants and Axes while using Tactile Cartesian Plane in Pretest & Posttest and Computer Assisted Cartesian Plane.
9. There is no significance difference within the mean difference scores of *Finding Points* on Quadrants and Axes while using Tactile Cartesian Plane in Pretest & Posttest and Computer Assisted Cartesian Plane.
10. There is no significant influence of Gender on *Plotting Points* and *Finding Points* on Quadrants and Axes and their interaction on Plotting and Finding by Considering Pre Tactile Score as covariate.
11. There is no significant influence of Grade on *Plotting Points* and *Finding Points* on Quadrants and Axes and their interaction on Plotting and Finding by Considering Pre Tactile Score as covariate.

1.17 Scope of the Study

1. Computer Assisted Cartesian Plane has a universal design feature and thus be useful to any learner.
2. Computer Assisted Cartesian Plane once developed can be used ‘n’ number of times and by ‘n’ number of learners.

3. Computer Assisted Cartesian Plane has three modes namely Learning, Practice and Evaluation, and thus has a holistic software system.
4. It can be used on offline mode and does not require an internet facility.
5. Computer Assisted Cartesian Plane has scope for further development of advanced software systems for mathematical concepts.

1.18 Delimitations

The following were the delimitations of the study

1. Due to scarcity of samples, the study is restricted to the only experimental group and no control group
2. The present investigation is an Experimental study was confined to 42 samples.
3. The demographic variable used in the study is restated to Gender only due to the non-availability of the sample as stated in the inclusion and exclusion criteria.
4. The study was confined to only Coimbatore district in Tamil Nadu
5. The study was confined to students with total vision impairment.

1.19 Organization of the Study

The present study on "**Developing Computer Assisted Cartesian Plane to Enhance Graph Sk ills of Students with Visual Impairment"** is organized and reported under the following chapters:

Chapter I : The first chapter presents Introduction, Blindness rates globally and in India, Historical Perspectives of Education for Blind, Education of the Blind in Pre - and Post- Independent India, Inclusive Education in India, Use of Technology in the Education of Visually impaired, Use of Technology in the Employment of Visually Impaired, Use of Technology in the Classroom, STEM Education for Visually Impaired, Science Education for the Blind, Importance of Mathematics Education, Technology and Use of Technology in Teaching Subjects for Blind Students, Rationale for the Study, Statement of the Problem, Terms used in the study, Objectives, Hypotheses, Scope of the study, Delimitations and Organization of the study are described.

Chapter II	**:**	The second chapter presents the review of literature related to the present study.
Chapter III	**:**	The third chapter explains the research procedure, which includes designing and developing of Computer Assisted Cartesian Plane, and its introduction among students with visual impairment, construction of tools, selection of samples, administration of the tools, and data collection procedure.
Chapter IV	**:**	The fourth chapter deals with the tabulation, analysis, and interpretation of data in detail.
Chapter V	**:**	The fifth chapter reports the findings, discussion, recommendations, and suggestions. This is followed by Bibliography and Appendices.

The review of related literature is presented in the next chapter.