

CHAPTER II

REVIEW OF LITERATURE

2.0 Introduction

In the first chapter, Rationale along with Objectives and Hypotheses have been given. The present chapter is devoted to reviewing researches related to different aspects of learning graphs by students with visual impairment, Graph skills, and other mathematical concept learning. For better understanding, the researches have been classified under the captions as follows. This chapter presents an overview of the available technology for Mathematics teaching for the visually impaired.

- 2.1 Education of students with Visual impairment
- 2.2 Inclusive Education for the Students with Visual Impairment
- 2.3 Tactile Medium of Learning for Students with Visual Impairment
- 2.4 Teaching Mathematics to Students with Visual Impairment
- 2.5 Challenges in Learning Mathematics by Students with Visual Impairment
- 2.6 Teaching Geometry to Students with Visual Impairment
- 2.7 Tactile Sense and Graph Education of students with Visual Impairment
- 2.8 Haptic Graphs for Students with Visual Impairment
- 2.9 Audio Tactile for Students with Visual Impairment
- 2.10 Graph Accessibility for Students with Visual Impairment
- 2.11 Graphical Challenges for Students with Visual Impairment
- 2.12 Use of Technology for Teaching Mathematics to Students with Visual Impairment
- 2.13 Use of Technology in Teaching Graph
- 2.14 STEM Education for students with Visual Impairment

2.1 Education of Students with Visual impairment

The challenges and opportunities of students with visual impairment in inclusive education were conducted with a case study design. The interview results indicated that inadequate budget, lack of necessary materials, absence of qualified professionals, shortage of professional growth, and development training were some of the major factors that hinder the full implementation of inclusive education. It was also concluded that the challenges outweigh the opportunity for the full implementation of inclusive education. As a recommendation, strong collaboration among stakeholders, non-governmental organizations along with the concerned bodies, training offered for professional teachers in special needs education, and appropriate budget allocation to realize the effective implementation of inclusive education was suggested (Belay & Yihun, 2020).

The status of inclusive education in India, for students with visual impairment, was explored. The objectives of the present study are to understand the concept of inclusive education in the 20th century; know the difference between inclusive education and special education; enumerate the problems of inclusive education in India; suggest ways and means solve such problems. From an extensive review of related literature, it has been found that it is difficult to have proper, functional inclusive set-ups in India. The major problems are lack of infrastructure, a trained teacher, funding, etc. However such education is important for students with visual impairment because in India about 2.21% of the total population is disabled, out of which 19% are visually impaired. Nobody likes to be treated differently. Inclusion increases self-confidence and helps these children to easily blend into the core of society (RumtiDas, Dr.IndraniGhosh (2018)).

The study on the perception of students with visual impairment, their peers without disabilities, and teachers about inclusive education, focusing on a second-cycle educational institution in the Eastern region of Ghana implementing inclusive education for the visually impaired were conducted. The finding revealed that students with visual impairment and some teachers supported inclusion while several students without disabilities disliked the practice. Some teachers indicated that the idea of inclusive education is a good way to ensure equal educational opportunities and they concluded that Ghanaian teachers in inclusive schools should be equipped with training

to teach students with disabilities. (Asamoah, Ofori-Dua, Cudjoe, Abdullah, & Nyarko, 2018).

The study focused on investigating the challenges facing students with visual impairment who are in open and distance learning models using prior empirical literature review was conducted. Findings using contents analysis have indicated that university social views, inadequate resources, and an unfriendly university environment are the main challenges affecting their academic progress. This study also recommended that the university should ensure that learning environments for people with physical disabilities have specific considerations in design and implementation to ensure their appropriateness and accessibility (Mngâ, Ngoboka, Kavenuke, & Ndekwa, 2017).

It is essential to build an inclusive society. Inclusion is more than a method of educating students with disability. To meet the challenges, the involvement and cooperation of educators, parents, and community leaders are vital for the creation of better inclusive schools. Therefore, inclusion arose as a good solution to the question of how to educate these children more effectively (Singh, 2016).

Understanding the issues teachers encountered when students with visual impairments transitioned to higher education was conducted. Difficulties identified were the inability of students to access and operate accommodations, problems with getting accessible materials in time for class, and the late arrival and poor quality of books transcribed into braille. Those teachers indicated that students who did not have enough training in using technology efficiently avoided its use altogether so as not to draw attention to them. (Reed & Curtis, 2012).

Inclusive education must respond to all pupils as individuals, recognizing individuality as something to be appreciated and respected. Inclusive education responding to special needs will thus have positive returns for all pupils. It is the school system of a country that must be adjusted to meet the needs of all its children (Rao, 2003).

Hartley's study (1963) emphasized that Blind students need to be taught according to a unique programme to help them learn simple concepts that sighted

students develop through incidental learning. This was also emphasised throughout the study carried out by (Agrawal, 2004) on programmed learning techniques. She found that programmed instructions help in constructing sequences of instructional material in a way that the rate of learning is maximised, motivation of the student is enhanced and understanding is fostered. Research studies, carried out in the field of special education, demonstrated that blind students can learn Mathematics when they are taught appropriately (Davidson, 1988); Darling, 1985; Kalaiselvi, 1985; Muthaiah, 1984; cited in (Agrawal, 2004)).

2.2 Inclusive Education for the students with visual impairment

Obstacles and challenges in inclusive education for children with special needs were studied. Many problems such as lack of well-educated teachers, curriculum, resources, good infrastructural facilities, awareness, positive attitude, plans, policies are creating hurdles for extending the concept of inclusive education in India (Sarao, 2016).

The challenges faced by students with visual impairment learning high school mathematics in inclusive classrooms were conducted with an exploratory study. The results indicated that the social needs of students with visual impairment were adequately met through inclusive education, their academic needs were not, which we speculate to be partly because of mathematics teachers' negative attitudes towards inclusive education. (Bayram, Corlu, Aydın, Ortaçtepe, & Alapala, 2015).

Prospects of inclusive education in India were studied. They expressed that Inclusive education is a process of strengthening the capacity of the education system to reach out to all learners. It involves restructuring the culture, policies, and practices in schools so that they can respond to the diversity of students in their locality. They focussed upon compensating these gaps with an optimistic motion for successful inclusion. (Mrunalini & Vijayan, 2014).

The study on preparing inclusive schools to meet the challenges of students with disabilities in India was conducted. The guidelines were derived from an empirical study that entailed examining prevalent practices and introducing inclusion in a regular school setting. Further, it is suggested that schools can implement inclusive

education programmes if they are adequately prepared, can garner the support of all stakeholders involved in the process, and have basic resources to run the programmes (Madan & Sharma, 2013).

Inclusive education has been recognized as a key strategy to ensure education for all in the developing world for the last two decades. The majority of the pre-service teachers have unfavourable attitudes to include students with special educational needs in regular classrooms. Misconception and lack of knowledge about disabilities are revealed from most of the pre-service teachers' responses (Malak, 2013).

Inclusion is more than a method of educating students with disability. To meet the challenges, the involvement and cooperation of educators, parents, and community leaders are vital for the creation of better inclusive schools. Therefore, inclusion arose as a good solution to the question of how to educate these children more effectively (Singh, 2016).

2.3 Tactile Medium of Learning for Students with Visual Impairment

Blind or visually impaired users typically access diagrams in the tactile medium TouchMelody is a system designed for augmenting such existing diagrams with 3D spatial auditory information to increase their usefulness, information content and reduce tactile clutter. The two major technologies used are the Polhemus FASTRAK and the LakeDSP CP4 to facilitate the creation of a directly manipulatable dynamic 3D spatial soundscape (Ramloll & Brewster, 2002).

The embossed graphs give quicker and correct access to the data than braille and electronic tables. Based on this observation, software for the creation of embossed graphs that can be operated by blind people was developed. Up until now, line graphs can be created with this software. Participants were three blind university students aged 19 to 21 who use braille every day. Four data sets representing four functions of the same condition (one of braille table, text file, and embossed graph) were presented to each participant all at once. The experimental results have shown that tactile graphs are more appropriate for blind people to grasp the relationship between two corresponding variables quickly and correctly than printed or electronic tables (Watanabe, Yamaguchi, & Nakagawa, 2012).

2.4 Teaching Mathematics to Students with Visual Impairment

Representative math textbooks from grades five, eight, and 11, aligned to the Common Core, were selected to investigate how much description is sufficient to communicate math content in different types of images. Mutually exclusive and exhaustive image categories were identified. Clear examples of each image category were chosen, and digital files were created containing the examples and surrounding textual material. Files replicated the printed page as closely as possible, and all elements (words, math expressions, and descriptions of images) were readable by JAWS. Forty-four students who are visually impaired listened to the math pages and answered questions related to the content contained in the images. Students answered content-related questions better with more description, but across four description conditions with varying amounts of description, the highest correct rate was low (29%). Students had the most correct answers for number lines (41.0%). Rates of 20% to 33% correct were demonstrated for image categories of shapes, tables, line graphs, bar graphs, and ray diagrams. Correct rates for equations, pie charts, and maps were inconsistent or lower than 15%. Students were positive about math and did not indicate many problems with math texts. Descriptions of visual images can communicate important math information, but there are images for which no level of description is sufficient. Many students in the study were not aware of how much visual math content to which they were not provided access (Emerson & Anderson, 2018).

The factors limiting the participation of blind and partially sighted learners in mathematics and science education were the teacher motivation and mentorship in mathematics and science methodologies and the use of tools for learner empowerment are lacking. It further revealed that teachers lack the requisite skills in special education to harness learner potential in mathematics and science. This situation necessitates government action in teacher training and development (Maguvhe, 2015).

A survey of the current status of students with visual impairment in secondary mathematics classes discussed mathematics teaching tools and other issues. The results of this survey showed that teachers encounter continuous difficulties in providing materials and equipment and few students are participating in more advanced mathematics (Rapp & Rapp, 1992).

2.5 Challenges in Learning Mathematics by Students with Visual Impairment

The problems faced by students with visual impairment in learning Mathematics at the secondary level in Rawalpindi and Islamabad-Pakistan were studied using a Qualitative research approach to explore the problems of students. A case study design was adopted and Semi-structured interviews were conducted with the participants. The Interviews were audio-recorded. Data analysis was done in stages. Firstly, data were transcribed, and next coding was done. It was found that students with visual impairment are facing diversified problems in learning Mathematics such as Fatigue, lack of interest and motivation, the behavior of teachers and administration, lack of skilled professional Mathematics teachers, and lack of equipment and resources for studying. It was recommended that institutions may provide the students with visual impairment with appropriate hardware and software facilities; also, teachers should be skilled in managing such students with visual impairment (Iqbal, Noor, Nadeem, Javed, & Shams, 2020).

The obstacles to learning maths by blind students from the perspectives of students and teachers were investigated. The sample of the study consisted of 30 students who are blind or visually impaired. To learn about the obstacles they faced in learning maths, a questionnaire was employed, which was verified in terms of validity and consistency. In addition, 2 maths teachers at blind schools in the Jordanian capital Amman were interviewed. The results showed that the obstacles were so high by 89, 3%, downwards for the following aspects: administrative 94%, cultural 89%, and curricular 85%. The researchers recommend providing supporting programmes and curricula which meet the needs of blind students in Jordan (Aljundi & Altakhayneh, 2020).

The qualitative responses of a survey of teachers of students with visual impairments in Canada and the United States about tactile and print graphic use by their students with visual impairments were collected. Questions focused on barriers to students using graphics, strategies taught to tactile graphics users, and profiles of successful tactile and print graphics users. The results indicated that generally, the teachers cited a range of challenges under the main themes of quality and instruction. Subcategories included availability of time for both production and instruction, lack of

standardization in material production, and student development of concepts through the use of graphics. The main characteristics of successful graphics users included motivation and an ability to apply skills across tasks. Variations in responses for tactile and print graphics users are highlighted (Zebehazy & Wilton, 2014).

2.6 Teaching Geometry to Students with Visual Impairment

The plastic geoboards and accessories were created as geometry teaching tools for visually-impaired students, using 3D printing. Lines, shapes, and angles were illustrated by stretching rubber bands around rivet heads on a geoboard with a square edge of a 10 x 10 grid array and the circular edge of a 4-quadrant graph. The coordinate points of 2D geometry were explored by blind touch on braille scales and raised grid lines, while z-axis pillars were used for 3D geometry by connecting rubber bands to the plane. The experimental group revealed significantly more learning achievement than did the control group, and all participants agreed that the new geoboards enhanced the mental imagery and understanding of geometry (Junthong, Netpradit, & Boonlue, 2020).

Geoboards improved learners' understanding of geometric theorems, especially understanding geometric terminology and reasoning. Recently, geoboards have become popular effective tools for teaching geometry to visually-impaired students. Geoboards can benefit teachers and students by helping to capture their explanation of a geometric concept for discovery or illustration by students with visual impairments, low vision, and normal vision. There are several teaching tools available on the market that can serve this purpose effectively; however, the imported products are too expensive. Therefore, teachers need to implement certain techniques to provide visually-impaired students with an effective math education by using braille cards. Mathematics teachers in schools for the blind always need geometry teaching tools for students who are blind or visually impaired (Sibiya & Mudaly, 2018).

The effect of applied orientation and mobility programmes on attitude and achievement in the geometry of learners with visual impairment was studied using experimental design. Two instruments were used: Attitude to Geometry Scale (AGS) and Adapted Geometry Task Performance Test (AGTPT). Three research questions and five hypotheses were used. The research questions were analyzed by the use of simple

percentages and mean. They found that 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. The high performance in geometry tasks changed from negative to a positive attitude of the learners towards geometry. The study showed that the adapted strategy had no effect on task performance and attitude towards geometry based on age at onset of visual impairment. The implications of the findings of this study are: Access and high task performance in geometry and mathematics, in general, will qualify the learners' entrance into tertiary institutions since today mathematics is used as a filter for entrance into tertiary institutions (Jurmang, 2015).

The text-to-diagram conversion allows students to input a geometry word problem into a system attached to a traditional Braille printer and then receive the underlying diagram on a Braille printout. This proposed solution to costly, ineffective technologies was evaluated through a seven-month study at a blind boys' school in India. While the results of this study showed a general comprehensiveness of the geometric shapes by the students, the results were ultimately inconclusive as to the effectiveness of such technology. The authors suggest there would have to be further research conducted based in the United States to determine the validity of the technology used in this study. Although Unified English Braille is not a sufficient tool for teaching mathematics, a simple adaptation could be useful in understanding printed graphs, shapes, or figures through this study's proposed method (Mukherjee, Garain, & Biswas, 2014).

2.7 Tactile Sense and Graph Education of Students with Visual Impairment

Experiences with tactile graphics and braille materials used in mathematics and science classes of 12 youths with visual impairment among 6th to 12th grades of students were studied. Youths answered questions and explored four tactile graphics made using different production methods. They located specific information on each graphic and shared their thoughts about the quality of the graphics. Almost all participants reported typically receiving braille materials and using tactile graphics in their mathematics and science classes. They reported that occasionally they do not have access to mathematics and science materials at the same time as their peers. Some seemed concerned by the lack of materials, and others did not. The lack of materials

may be problematic since some of the students reported completing the assignments later or not at all. Youths overwhelmingly reported a need to have tactually distinctive elements in graphics. so they suggested Professionals that should consult youths when preparing materials for them for use in mathematics and science classes. Additionally, youths who are tactile readers need direct instruction in how to measure objects as well as how to locate specific information in a variety of graphics prepared using different production methods (Rosenblum & Herzberg, 2015).

The responses of a survey of students with visual impairments in Canada and the United States about their use of tactile and print graphics were analyzed. Demographic, Likert scale and open-ended questions focused on perceptions of quality, preferences, instruction, and strategies. Percentages of the agreement for tactile and print graphic users are reported. Comparisons were made between the two groups. The results found that students felt positive about the quality of the graphics, but density and complexity were identified as challenges. Students varied as to whether they felt graphics supported their understanding of concepts. They also discussed that tactile graphics appear to play an additional role in inclusion for some students. Attention to instructional needs should not overlook students with visual impairments who use print graphics. Additional inclusion of quality written descriptions may support understanding of graphical information. (Zebehazy & Wilton, 2014).

The comprehension and interpretation of raised-line images and graphs by touch were investigated using two experiments. Experiment one required blind-folded sighted subjects and blind subjects to rate the veracity of raised-line drawings in conveying the nature of an image when the complexity of the depicted object was manipulated (from simple outlines to more complex exaggeration of salient features). Results showed no effect of complexity on veracity ratings. Experiment two involved the assessment of blind and visually impaired subjects of line-graphs, histograms, and pie charts which varied in information content and perceptible detail (textured and untextured). Histograms were easier to interpret than line graphs, but there were no differences between histograms and pie charts. An increase in information content had little effect on comprehension. (Pring & Walker, 1993).

Simple formats, line graphs, were chosen and argued that a relatively direct translation from the standard visual format would provide sufficient information to the haptic system for effective tangible-graph reading performance. The results suggest that the presentation of spatial information in the form of tangible graphs is indeed a viable source of information for the blind reader, regardless of age at onset or duration of total blindness. Of the four graph designs evaluated, the grid-on-graph and grid-underlay modes proved most effective in terms of performance and preference. Exploration strategies and design improvements were also considered (Lederman & Campbell, 1982).

2.8 Haptic Graphs for Students with Visual Impairment

Locating Haptic points to test the efficacy and efficiency of the system and to determine patterns of user interactions with the touch screen was examined with a usability study. The results showed that: (1) participants correctly located haptic points with an accuracy rate of 69.83% and an average time of 15.34 s out of 116 total trials, (2) accuracy increased across trials, (3) efficient patterns of user interaction involved either a systematic approach or a rapid exploration of the screen, and (4) haptic elements placed near the corners of the screen were more easily located. Their user-centered design approach resulted in an intuitive interface for people with visual impairments and laid the foundation for demonstrating this device's potential to depict mathematical data shown in graphs. (Bateman et al., 2018)

Material perception in blind participants to explore the influence of visual experience on material representations and the relationship between visual and haptic material perception was investigated. Congenitally blind participants were made to explore different materials haptically and rate several material properties to assess the role of the visual sense for the emergence of haptic material perception. Principal components analyses combined with a procreate superimposition showed that the material representations of blind and blindfolded sighted participants were highly similar. (Baumgartner, Wiebel, & Gegenfurtner, 2015).

The use of a haptic touchscreen to convey graphical and mathematical concepts through aural and/or vibratory tactile feedback was examined. They hypothesized that an important application of such a display will be in teaching students with visual

impairment concepts that are traditionally learned almost entirely visually. This study described initial feasibility studies using a commercially available haptic touchscreen to display grids, points, lines, and shapes - some of the first visual graphical entities students encounter in K-12 mathematics education, and from which more complex lessons can be constructed. They conducted user studies designed to evaluate the perception of these objects through haptic feedback alone, auditory feedback alone, and combinations of the two. Their results indicate that both sensory channels can be valuable in user perception. (Toennies, Burgner, Withrow, & Webster, 2011)

The ability of visually impaired participants to make comparisons between haptic and audio line graphs was investigated through a think-aloud study. Graphs with two data series were presented. One data series was explored with a PHANTOM haptic device, whilst the other was sonified using one of two data - sound mappings. The results show that participants can make comparisons between the two lines. However, there is some cross-modal interference which makes it difficult to extract detailed information about the data series presented in audio. (D. McGookin & Brewer, 2006).

The development and evaluation of Web-based multimodal graphs designed for visually impaired and blind people were described. The information in the graphs is conveyed to visually impaired people through haptic and audio channels. The motivation of this work is to address problems faced by visually impaired people in accessing graphical information on the Internet, particularly the common types of graphs for data visualization. In their work, line graphs, bar charts, and pie charts are accessible through a force feedback device, the Logitech WingMan Force Feedback Mouse. Pre-recorded sound files are used to represent graph contents to users. To test the usability of the developed Web graphs, an evaluation was conducted with bar charts as the experimental platform. The results showed that the participants could successfully use the haptic and audio features to extract information from the Web graphs. (Yu, Reid, & Brewster, 2002)

The design of computer-based haptic graphs for blind and visually impaired people with the support of their preliminary experimental results was discussed. Since visual impairment makes data visualisation techniques inappropriate for blind people,

developing a system that can make graphs accessible through haptic and audio media. The disparity between human haptic perception and the sensation simulated by force feedback devices is discussed. Our strategies to tackle technical difficulties posed by the limitations of force feedback devices are explained. Based on the results of experiments conducted on both blind and sighted people, we suggested two techniques: engraving and the use of texture to model curved lines on haptic graphs. Integration of surface property and auditory cues in our system are proposed to assist blind users in exploring haptic graphs. (Yu, Ramloll, & Brewster, 2000)

2.9 Audio Tactile for Students with Visual Impairment

Teaching materials based on Audio tactile which is valid, practical, and effective to improve learning motivation and achievement of students with visual impairment were developed. The data collection techniques in this research were observation, interview, documentation, and tests. The conclusions of this study were the product was developed as a set of audio-tactile teaching materials which consisted of learning audio sources and tactile media. These audio teaching materials were supported by several tactile media such as planes, puzzles, geoboard, tactile rules, and tactile protractors. The Audio Tactile teaching materials can improve the learning motivation of students with visual impairment. The increase in learning motivation was indicated by high students' will to study, students' high perseverance, students' enjoyment, and curiosity. The Audio tactile teaching materials gave great positive impacts on learning achievements. This is shown by the increasing score of the posttest compared to the score of the pretest. (Arlinwibowo & Retnawati, 2015)

Access to digitally stored numerical data is currently very limited for sight-impaired people. Graphs and visualizations are often used to analyze relationships between numerical data, but the current methods of accessing them are highly visually mediated. Representing data using audio feedback is a common method of making data more accessible, but methods of navigating and accessing the data are often serial in nature and laborious. Tactile or haptic displays could be used to provide additional feedback to support a point-and-click type interaction for the visually impaired. Requirements capture conducted with sight-impaired computer users produced a review of current accessibility technologies, and guidelines were extracted for using tactile feedback to aid navigation. The results of a qualitative evaluation with a prototype

interface are also presented. Providing an absolute position input device and tactile feedback allowed the users to explore the graph using tactile and proprioceptive cues in a manner analogous to point-and-click techniques. (S. Wall & S. Brewster, 2006)

2.10 Graph Accessibility for Students with Visual Impairment

Forty students with visual impairment completed multiple-choice question tasks for five types of graphics presented in their medium of choice and provided difficulty ratings. The teachers of students with visual impairments rated the students on several factors. Statistical analyses investigated the relationship between performance differences and teacher-rated factors. Significant differences in performance between print and tactile graphics users were found for bar graph, map, and total correct responses on all tasks. For some tasks, perceived difficulty by tactile graphic users did not align with actual performance. Teachers' ratings of students who had Individualized Education Program goals for graphics, independence in using graphics, problem-solving ability, mathematics ability, and frequency of engaging with graphics contributed to significant differences in performance across total correct and most individual graphic results. Although the medium type was a significant contributor across graphic types, some teacher-rated variables appeared to mitigate the importance of medium on student performance. Depending on the graphic type, experience, content knowledge, skills with graphics, and confidence and motivation can all affect student performance when interpreting graphics. They concluded that the Teachers should provide students with early and frequent opportunities to engage with graphics and support their problem-solving abilities regarding how to engage with different graphic types to enhance their independent use of graphics. (Zebehazy & Wilton, 2021).

Graph accessibility and comprehension for students with visual impairments in high school mathematics courses were explored. The results suggested that (a) professionals who serve them with graphical information encompass more than mathematics teachers and Teachers with visual impairment (b) onset of visual experience carries weight when considering the types of assistive technology and instruction students utilize to access and comprehend graphical information, and (c) each Student has a unique set of approaches and challenges with graphs, even those with similar onsets of visual impairment. (Nashleanas, 2018).

A concept for 3D printed tactile graphics, which offers to use audio-tactile graphics with usual smartphones or tablet computers was presented. By using capacitive markers, the coupling of the tactile graphics with the mobile device is simplified. These tactile graphics integrating these markers can be printed in one turn by off-the-shelf 3D printers without any post-processing and allow us to use multiple elevation levels for graphical elements. Based on the developed generic concept of visually augmented audio-tactile graphics, they presented a case study for maps. A prototypical implementation was tested by a user study with visually impaired people. All the participants were able to interact with the 3D printed tactile maps using a standard tablet computer. To study the effect of visual augmentation of graphical elements, they conducted another comprehensive user study. They tested multiple types of graphics and obtained evidence that visual augmentation may offer clear advantages for the exploration of tactile graphics. Even participants with a minor residual vision could solve the tasks with visual augmentation more quickly and accurately. (Götzelmann, 2018).

The production and interpretation of perspective drawings by blind and sighted subjects were examined using three experiments. Blindfolded sighted, early-blind, and late-blind subjects first attempted to produce raised-line drawings of a surface at some angles-0 degree (panel horizontal), -22.5 degrees, -45 degrees, -67.5 degrees, and -90 degrees (vertical). Congenitally blind subjects did not show foreshortening in their naive raised-line drawings. However, the congenitally blind subjects were able to understand aspects of perspective and performed as well as the blindfolded sighted and late-blind subjects in a subsequent multiple-choice task. Subjects in the multiple-choice task were required to match tangible perspective drawings to a slanted board. Although the three groups performed alike, both groups of blind subjects performed better than blindfolded sighted controls on judgments involving drawings of the vertical panel in the second experiment. In a final experiment, in which vision and touch were compared, sighted subjects were required to adjust the angle of the panel to match foreshortened, perspective drawings. This experiment yielded significantly better performance with vision than with touch, but only for drawings of the board at the vertical orientation. The results suggested that congenitally blind people may benefit

from haptic exposure to raised-line configurations representing geometric perspectives. (Heller, Calcaterra, Tyler, & Burson, 1996).

2.11 Graphical Challenges for Students with Visual Impairment

43 students with visual impairment in grades 4 to 10 required significantly more help from teachers of students with visual impairments when solving math word problems that involved graphics (such as maps, diagrams, and geometric figures) compared to similar math problems that did not include graphics was found. Of the 16 braille readers in the study, only 5 were independent with the 16 problems that included graphics; the other 11 needed some level of assistance on at least one of the problems. Similar results were reported for the 27 print readers, and only 9 worked independently on all 16 graphics problems. (Rosenblum, Cheng, & Beal, 2018). The level of assistance the teachers of students with visual impairment provided to the students in this study would not have been permitted on high-stakes tests (Allman, 2009).

An online survey of 71 vision-impaired university students and semi-structured interviews with 44 key stakeholders (students, academics, disability liaison officers, and accessible graphics providers) to understand the current state of accessible graphics provision in Australian higher education was conducted. The results found that difficulty in accessing graphical materials was a barrier to many vision-impaired students and that there were systemic problems with current processes for accessible graphics provision. Recommendations are made on ways to address these concerns to provide a more equitable higher education experience. (Butler, Holloway, Marriott, & Goncu, 2017).

The challenges graphics present for students with visual impairment were reported. A survey of teachers of students with visual impairment found that only about 20% felt their students could use math graphics independently. The students with visual impairment were self-reported that they were not able to keep up with sighted classmates on math tasks that involved graphics. Most teachers of students with visual impairment indicated that the primary problem for their students was that they had not received explicit instruction in using graphics. Although the Guidelines and Standards for Tactile Graphics (Braille Authority of North America, 2010) provides support for preparing tactile graphics for braille readers, there are no guidelines for teachers of

students with visual impairment on how to introduce graphics to their students or how to teach them the systematic use of graphics as tools to gather information, nor are there guidelines on preparing graphics for visually impaired print readers. To gather preliminary information to guide our research team as we developed materials to support students with visual impairment in building their graphic literacy skills, we conducted three focus groups with 11 teachers of students with visual impairment. (Zebehazy & Wilton, 2014)

2.12 Use of Technology for Teaching Mathematics to Students with Visual Impairment

Current evidence-based knowledge about e-learning in mathematics among students with severe visual impairment was summarized. A systematic review was conducted of articles published from January 2000 to November 2017. They concluded that interactive e-learning with audio and tactile learning programmes may be a useful resource for students with Visual Impairment to enhance their mathematical skills. However, there is a lack of evidence for how digital technologies improve inclusion potentials and learning in mathematics for students with Visual Impairment, and hence, there is a need for additional research and more reflection on the subject. (Klingenberg, Holkesvik, & Augestad, 2020).

Perspectives of teachers of students who are visually impaired regarding the use and effectiveness of high-tech assistive technology purported to assist students with visual impairment in advanced mathematics were examined. A total of 82 surveys were completed through the device matrix question. Results indicated that 20 of the 35 technologies were used; of these, 13 were used regardless of the subject. More than half of the participants indicated that the same four technologies were implemented for student information access during class, guided practice, and independent practice. Participants recommended seven technologies not included in the device matrix through the open-response questions. (DePountis, Pogrund, Griffin-Shirley, & Lan, 2015).

The Feasibility of using an iPad application or “app” for algebra-readiness mathematics, with accompanying braille materials and accessible graphics, when used in authentic educational settings was evaluated. Twenty-nine students with visual

impairments in grades 4 -11 used the materials under the direction of their teachers of students with visual impairments. Twenty percent of the mathematics problems included graphics such as maps, line graphs, and bar graphs. Students and teachers of students with visual impairments provided feedback about the feasibility of using the app with supplemental materials and made suggestions for additional features to improve the instructional package. This study resulted that the students completing 984-word problems and solving 80% of them correctly within three attempts. (Beal & Rosenblum, 2015b).

An online survey of teachers of students with VI (TVIs) guided the decision to provide the math content in the form of an iPad app, accompanied by print and braille materials to make an online tutoring program for math word problem solving accessible to students with visual impairments (VI) was conducted. The app includes audio descriptions of images that illustrate the math problems, an integrated Scratch Pad, options to adjust color and contrast, hints, and videos showing how to solve sample problems. To provide access to those needing screen reading technology or screen enlargement, the app utilizes the Apple built-in accessibility features of VoiceOver and Zoom. A study with 19 TVIs and 29 students with VI was conducted to obtain feedback about the app and materials. Comments were generally positive, but both students and teachers reported that the quality of the hints varied and that the videos were not very helpful. Thus, the hints were revised and narrated videos showing step-by-step solutions were added to each problem. A single-subject study is in progress to compare students' performance when using the app and materials with the traditional way they access math materials both in print and Braille. (Beal & Rosenblum, 2015a).

Twenty haptics-based computer applications (apps) have been created to utilize a low-cost, force feedback haptic device, the Novint Falcon, to provide students with visual impairment with tactile and kinesthetic sensations while learning about math and science. These were added to the accessible resources available for math and science. The results of testing six of the apps in classroom settings show that the device and software are feasible for teachers to implement and significant learning gains can be achieved for students who use them. Student attitudes toward the apps were positive, implying that not only are the apps useful in the classroom but engaging as well. (Murphy & Darrah, 2015)

The use of assistive technology among high school students with visual impairments in the state of Illinois was conducted. The study reported that only 42% of high school students used high-tech assistive technology. Kelly draws attention to the fact that students with visual impairments who study in non-residential schools fall behind their sighted classmates. On the other hand, students who are placed in residential schools are more likely to use assistive technology (Kelly, 2011).

2.13 Use of Technology in Teaching Graph

Optimal methods for representing mathematical elements of graphs with sound were investigated. The results indicated that the methods of design in this study are effective for describing mathematical elements of graphs, such as axes, quadrants, and differentiability. These findings can help visually impaired learners to be more independent, and also facilitate further studies on assistive technology (Kim, Lee, & Seo, 2019).

An appropriate representation of numerical data to blind people was investigated. Its results have shown that embossed graphs give quicker and correct access to the data than Braille and electronic tables. Based on this observation, they started developing software for the creation of embossed graphs that can be operated by blind people. Up until now, line graphs can be created with this software (Watanabe et al., 2012).

Graph Builder, a novel application that allows visually impaired people to interactively construct bar graphs using a force feedback device was introduced. Evaluations of Graph Builder showed that users could construct graphs accurately. However, results showed that a large number of 'off-by-one' errors occurred, where the bar was set either one unit too high or too low. Revisions to the mechanism to manipulate bars were made, and further non-speech audio feedback was added. A further evaluation showed that the proportion of 'off-by-one' errors had been reduced. (McGookin, D. K., & Brewster, S. A. 2007)

Problems with inaccessible mathematical graphs by visually impaired people were discussed. By a review of graph understanding theory and interviews with visually impaired users, they explained the current non-visual representations are

unlikely to provide effective access to graphs. They propose the use of multiple views of the graph, each providing quick access to specific information as a way to improve graph usability. They then introduce a specific multiple view system to improve access to bar graphs called Sound- Bar which provides an additional quick audio overview of the graph. An evaluation of Sound Bar revealed that additional views significantly increased accuracy and reduced time taken in a question-answering task. (D.K. McGookin & Brewster, 2006).

Guidelines that will enable designers to implement visualisation systems for blind and visually impaired users, and will provide a framework for researchers wishing to investigate the audio presentation of more complex visualisations were explained. The guidelines are (i) include non-speech audio in tables (ii) informs users when they reach a table boundary (iii) Provide access to location information at all times (iv) Interrupt speech, when a task is halted (v), Provide table navigation shortcuts (vi) Do not use different pitches for speech input and (vii) Use one voice for speech output. (L. M. Brown, Brewster, Ramloll, Burton, & Riedel, 2003)

The development of a multimodal data visualisation system was introduced. This system is designed to improve blind and visually impaired people's access to graphs and tables. Force feedback, synthesized speech, and non-speech audio are utilised to present graphical data to blind people. Through the combination of haptic and audio representations, users can explore virtual graphs rendered on a computer. Various types of graphs and tables have been implemented and a three-stage evaluation has been conducted. The experimental results have proven the usability of the system and the benefits of the multimodal approach. (Yu & Brewster, 2003)

Accessibility of line graphs to blind and visually impaired people through the use of non-speech audio was presented. A method of sonifying two data series and the design of two modes (parallel mode and serial mode) for browsing the graphs were described. The quantitative evaluation showed that both browsing modes were successful, with the parallel mode being particularly effective. (L. Brown, Brewster, Ramloll, Yu, & Riedel, 2002).

The development and evaluation of Web-based multimodal graphs designed for visually impaired and blind people were described. The information in the graphs is

conveyed to visually impaired people through haptic and audio channels. Problems faced by visually impaired people in accessing graphical information on the Internet, particularly the common types of graphs for data visualization was addressed. Line graphs, bar charts, and pie charts are accessible through a force feedback device, the Logitech WingMan Force Feedback Mouse. Pre-recorded sound files are used to represent graph contents to users. To test the usability of the developed Web graphs, an evaluation was conducted with bar charts as the experimental platform. The results showed that the participants could successfully use the haptic and audio features to extract information from the Web graphs. (Yu et al., 2002)

The use of the Graphics and User's Exploration via Simple Sonics (GUESS) system in the exploration of auditory pattern perception by blind and visually impaired people was studied. Comparison of three different techniques for presenting graphical scenes via non-speech sounds: one based on the physical tablet, one on the virtual-sonic grid, and one on sound localization techniques were done. The results have shown that with the second and third techniques, blind people were able, within a relatively short space of time, to precisely identify the interrelation of simple geometric shapes. They have also shown that, in the second technique, assigning a non-speech sound to a region located in the center of the tablet reduced the navigation time when relocating specific shapes. As to the first technique, it received the lowest time rating for relocating objects. Their findings indicate that the method of presenting interrelation in auditory interface designs does indeed play an important role in assisting users to comprehend the diagrams communicated. (Kamel, Roth, & Sinha, 2001)

Interrelations are often represented as diagrams. With the aid of a touch panel and auditory display, AudioGraf enables blind and visually impaired people to read such diagrams. The diagram is displayed on the touch panel where a part can be selected with a finger. A model of this audio-tactile exploration is presented. Based on this model it is explained how AudioGraf supports the user. Usability tests have shown that simple diagrams can be read by blind users within a relatively short time (Kennel, 1996).

2.14 STEM Education for Students with Visual Impairment

The nature and need of STEM education for promoting academic and vocational success among individuals with Visual Impairment was explored. The findings revealed that there is an immense need for STEM education among Persons with Visual Impairment. Currently, educators and trainers are utilizing curriculum adaptations to impart STEM education. However, there is a lack of awareness of the latest techniques and technologies to effectively impart STEM among those with visual impairment. Hence, there is a need for exposure to STEM education through accessible and universal methods and strategies for individuals with blindness and other forms of visual impairment for better skill development and ensuring success in life (Sampurna Guha 2019).

Youth between the ages of 10-18 related to their experiences of accessing math and science-related content in schools were surveyed. The most common methods currently used to access these materials in class and the various combinations of low-tech and high-tech solutions at their disposal, including print, braille, and various means for performing calculations was shared. While the vast majority of youth reported having a Teacher of the Visually Impaired or aid who helped them with math and science work, 82% reported having trouble accessing information that teachers put on the board most of the time or occasionally. Youth were overall positive about their desire to learn math and science in school. However, they also reported that factors such as receiving their materials later than classmates, not having visual concepts adequately explained, and classroom teachers' general lack of comfort while working with these youth were all cited as deterrents to learning (Bell & Silverman, 2019).

A new type of tactile 3D image was developed using High-Density Polyethylene (HDPE) and Computer Numeric Control (CNC) milling. To determine the discernibility and effectiveness of tactile images, these customizable boards were tested in various university classrooms as well as in participation studies which included Blind, Visually Impaired and sighted students. Results from these indicated that tactile images are discernable and were found to improve performance in lab exercises by as much as 60% for those with visual impairment. Incorporating tactile HDPE 3D images into a classroom setting was shown to increase the interest, participation, and

performance of Blind and Students with visual impairment suggesting that this type of 3D tactile image should be incorporated into STEM classes to increase the participation of these students and improve the level of training they receive in science and mathematics (Gonzales, 2015).

2.15 Conclusion

This research review purpose is to help the reader understand different aspects of education of students with visual impairment particularly focusing on math education. There has been much research and discussion conducted on teaching graph to students with visual impairment including tactile models and technology based teaching. Most of the research found was on tactile models and a few studies related to technology components but the effectiveness of such technology to learn graph skills by students with visual impairment needs to be established. More testing is required to gain better understanding of how technology is useful and why the students with visual impairment are struggling to identify themselves with their peer groups. Research on the Literature review revealed that in countries like the United States, math education which are visually oriented have been modified to the needs of students with visual impairment.

But in Indian context, such modification/adaptation or development of new devices for math education is rarely noted. Hence the present research was planned to develop a computer assisted Cartesian plane as a teaching-learning tool and study its effectiveness by introducing to students with visual impairment in learning Cartesian plane which is critical concept to be conceptualized for real life situation.