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TRENDS AND CHALLENGES IN THE WORLD OF THE BLIND FOR EDUCATION IN MATHEMATICS

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Abstract

The present world is full of training frameworks that include graphical and digitized arrangements for people with normal vision. For visually impaired people evolving such training frameworks remains a challenge. Blind people, particularly those who are passionate about establishing themselves in the fields of science and mathematics, are finding it difficult to continue their study. The lack of training frameworks that can assist children in learning graphic three-dimensional structures, mathematical symbols, and equations is the fundamental cause for this. Learning and understanding mathematical concepts is quite hard for primary and secondary education of blind people, which subsequently hinders their career choices and career growth. The purpose of this research is to review the present status, current trends and tools that are available to blind people to learn subjects in the field of the mathematics and science. The study also includes the future perspectives and challenges for vision disabled learners in the field of mathematics. The present study has collected data from two blind schools to exhibit the challenges in learning mathematics. Samples were chosen from students and professionals engaged in mathematics teaching and learning to understand the ground-level user needs and challenges.

Keywords: blind users, Braille, mathematics, slate and stylus

1. INTRODUCTION

To enhance the beauty of the world, nature gifted human with eyes so everyone enjoys this wisdom of nature. Whereas education helps human to get higher position in society and a professional environment. Education enhances our growth and development but still the presence of unfortunate people who are deprived of the same due to vision disability (blinds) cannot be ignored. Education always turns weakness of human being into strength, thus vision disabled people must earn good level of education which may give them more confidence, security, and financial stability in society.

According to the author, understanding and valuing the individual selections made by blind/vision-impaired people will aid people in making post-school options. You must decide what topics to study, what courses to take, what vocation to pursue, and where and from whom to seek help during this period [1]. According to research, interacting with the maths syllabus is very difficult for blind/vision-impaired people, and achievement in this subject is particularly low for those who have little or no vision. This poor level of accomplishment has a knock-on consequence on the number of blind/vision-impaired apprentices who go on to higher education [2]. According to Indian study, the

mainstream of blind apprentices take maths at a junior level, restricting their access to advanced education schemes. According to Indian study, the mainstream of blind students take maths at a lower level, restricting their access to junior education streams. Because mathematics is mostly visual, two-dimensional, and non-linear, it can be difficult to present. Because Braille isn't always ideal for mathematics notation, graphical–spatial mathematics topics like tables and graphs are thought to be particularly difficult for people with severe vision problems [3].

Additionally, while speech synthesisers are helpful while using word processors, they aren't always accurate when it comes to math [4]. Participants were able to follow up with the content on their own, according to Whitburn [5], thanks to clear vocal descriptions of complex mathematical issues. According to Shute, Graf, and Hansen [6], teaching visual content to blind/vision-impaired students becomes more challenging as visual content grows more complicated. As a result, while extensive descriptions may serve for simple charts and figures, they may fall short for more complex mathematical elements. As a result, while extensive descriptions may serve for simple charts and figure, they may fall short for more complex mathematical elements.To guarantee that blind children can attain their full possible when fetching with the math program, a "variety of adaptable and supportive teaching strategies" (Matthews [7.] is required. Regardless of their preparedness and planning, students will drop out of secondary schooling [8]. As a result, it is critical to recognize that one of the most important goals of education is to help students make successful post-school changes and to provide them with the required and suitable guidance. The part of the career supervision counselor in the secondary school context, and specifically in the function of the profession direction counselor, is to assist young people in making an effective transition.

No doubt blind people are being educated through a Braille system that is providing them a platform for learning, but the problem arises when blind students have to sense mathematical shapes and symbols as Braille is a code-based system. In India, the teaching-learning process of mathematics has always been challenging. A large number of students drop the subject mathematics when the higher education starts. The main reason is the increasing difficulty level in mathematics and lack of teaching aids; blind students opt for substitution subjects offered by different state boards. As a result, the choice of mathematics is ruled out by most of the blind students. Different educational boards have provided choice of different subjects to select and made mathematics subject as optional. The reason is the task of simple calculation seems to be mammoth challenging for vision disabled as it is visually half baked and lacks registering the logic of sensing shapes, geometry, complex equations, and their respective symbols. It becomes difficult nut to crack for blind students. The main challenge for the secondary level of education in mathematics for blind students is the lack of availability of graphical representations of shapes and symbols [9]. Thus the provision of optional choices in place of mathematics subjects has become the default choice for vision disables. Teachers and parents also prefer the optional choices in place of mathematics. There is a compelling need for researchers, scientist and community to focus to development of tools and technology so that the vision disables can be educated with the higher level of education especially in the field of mathematics and science.

2. Existing State-of-Art

Different researchers and communities worked in different areas to develop hardware and software technologies, which will be teaching aid for blind students. The technology will help the blind students in learning and analysis graphical representations and graph mathematical concepts more effectively. Still it is a big challenge for our society; to develop effective solutions to meet the need of such people. Table 2(a) provides the detailed technologies developed so far to assist blind students in learning

Table. 2(a) The Existing Sate of Art for Hardware Technologies for Blind People

Year of Publications	Author/s	Summary
2019	Soiffer N et al [10]	Current methods convert Math Ml to voice and Braille and allow users to traverse expressions for greater understanding.
2019	Karadag O et al [11]	This paper proposed a mathematics and geometry device for the visually impaired, consisting of (1) retractable push-buttons (2), at least one button body (4), which allows the push-button to be placed on the socket (3) and make a linear movement towards the inside-outside of the device when the push-buttons are pressed; and at least one lock system, which is located on the button body and allows the button body to be locked in upper and lower positions when the button body is pressed; and when the button body
2018	Ashby et al [12]	This paper depicts the first step in using an established, valid, and consistent longitudinal capacity instrument – the Mental Cutting Test (MCT) – to measure altitudinal capacity among people who are blind or have poor vision (BLV). The researchers are adapting the instrument by making three-dimensional (3-D) reproductions of present MCT queries so that persons with BLV can feel the test with their hands.
2005	Hamid Reza et al [13]	In this research the outcomes is Optical Braille Recognizer (O.B.R.) and the design of a Braille code keyboard. The

		main purpose was to enable tutors of blind students who are not aware from the Braille code to see the texts that their students had written. It was designed to be a quieter and a cheap electronic keyboard than old-style mechanical keyboards.

In this digital era, the multimedia solutions are highly required for blind students. Software technology has been focused by many researchers[14-15].Braille reading ,writing software's/Translators etc have been developed .Table 2(b) summarize the e existing state of art of software technologies developed for blind people.

Table. 2(b) The Existing Sate of Art for Software Technologies for Blind people

Year of Publications	Author/s	Summary
2019	Van Leendert A [14]	The investigation revealed that reading and solving problems using mathematical expressions took the two experienced Braille readers around 3.5 times as long as print readers. For all items, the Braille readers used personal reading strategies with little regard for the structure of the expression.
2019	Pehlivan S et al [15]	Combining auditory and tangible senses to warn the user was developed in this research. The eSpeak system alerted the user via headphones, construing the name of the sensed object. Three vibration sensors were installed in the right, center, and left positions at the same time. When an obstruction was discovered inside one of the predetermined bounding boxes, the associated tremor sensor was initiated with the name of the object.
2019	Brzostek-Pawłowska J [16]	This paper shows interactive multimedia solutions created as part of the author's two research projects. The aforementioned solutions improve mathematical communication. The results of qualitative surveys on novel solutions are presented, confirming their utility and the demonstrable impact they have on the group's mathematical problem-solving efficiency.
2018	JoeTekli et al [17]	A specific experimental technique, dubbed EVIAC, is used in this research to assess a blind user's ability to learn, discern, identify, and recognize basic forms and geometric objects shown on a

		vibrating touch-screen. A battery of evaluation metrics was used on blindfolded and blind candidates, including: i)Figure recognition accuracy, ii) Samples' average response time, iii) Amount and period of finger strokes, iv) Outward zone covered by the samples' finger path trails, and v) member path relationship with the external of the target shape.
2018	OrlyLahav et al [18]	According to this study, intuitive interference is caused by immediate perceptual changes, which are frequently visual. In studies with seeing participants, it was discovered that when "perimeters" were compared.
2017	Muscat A et al [19]	In this work researcher presents the instinctive group of spatially anchored image imageries as a three-step task, with the first step identifying items in an image, the second step detecting 3-D relations between object couples based on verbal and graphic features, and the third base step mapping spatial relationships to natural language.
2017	Asebriy Z et al [20]	A method that aids blind persons in classifying mathematical formulas from electronic documents. The system works in four steps: first, the query math formula is translated into Presentation MathML code, and then the structural and semantic meaning of the MathML expressions is extracted.
2017	Julie Ducasse et al [21]	This paper conducted an extensive assessment of collaborative map prototypes, categorizing present collaborative plans into two different types: Digital Interactive Maps, which are demonstrated on a smooth exterior such as a shelter, and Hybrid Interactive Maps, which contain both a digital and physical illustration.
2016	Pinho TM et al [22]	This study looked at a lot of interactive map prototypes and divided them hooked on deuce types: digital interactive maps

		(DIMs), which are exhibited on a flat exterior like a screen, and mixture collaborative maps (HIMs), which contain both a numerical and a corporal illustration.
2016	Kapperman G et al [23]	The product proposed in this paper was based on Braille notes. They created a software programmer to improve Nemeth Code's efficiency.
2016	Catherine Baker et al [24]	The development of Tactile Graphics with a Voice (TGV), a system that uses QR codes to retrieve label information in tactile graphics, is discussed in this study. Tactile graphics are frequently used by blind students to view textbook visuals. There are a lot of text labels on many textbook photos that need to be made accessible. To accomplish so, they offer TGV, a text replacement system that uses QR codes instead of Braille. A Smartphone application is used to decipher the codes.
2015	SamerIsayed et al [25]	The Optical Braille Recognition (OBR) methodis proposed in this study, to convert the content of a Braille document image into natural language characters (OBR). Braille cell recognition and transcription are the two key phases involved. Image capture, image de-skewing, image pre-processing, dot recognition, cell recognition, and segmentation are some of the procedures involved in Braille cell recognition. The goal of image record is to translate the segmented Braille cell into natural language characters.
2014	Abdul Malik S et al [26]	In this paper, a Braille Copier (BC) creates a plain Braille paper copy of the original document with the precise format, regardless of the language. Optical recognition and image processing techniques are used in their strategy.
2014	Baboo, D. S et al [27]	The adaptive thresholding technique, which was used to isolate the Braille dots from the backdrop in this work, is an

		effective technique that produces excellent results in more than 90% of the photos. Morphology approaches can aid in the noise reduction of an image. A skew angle is always present in the acquired image (or the image has a rotated angle in the 3rd axis).
2013	Aisha Mousa et al [28]	This research employed a combination of strategies to provide a reliable and accurate system for converting Braille texts to written text. However, this technique is cost-effective, as it does not require the purchase of expensive specialized scanners.
2012	Bernhard Schmitz [29]	This research investigated a system that can assist blind people in gaining an idea of the layout of unfamiliar regions, as well as improving their comprehension of familiar areas.
2010	Isaacson MD et al [30]	The efficacy of Math Speak rules for disambiguating oral representations of spoken mathematics was investigated in this work. Math Speak appears to be effective in deciphering spoken mathematics, according to the findings.
2010	Anna M et. al.[31]	In this article, teachers of children with visual impairments can create a community of Braille enthusiasts in the classroom utilizing affordable supplies and a minimal amount of effort.
2010	Bernardine Dias et al [32]	The promise of expanding admittance to tangible graphics in emerging countries using a software tool that converts photos to a form that may be published as tangible images using low cost Braille text printers is discussed in this work. They test the tool's efficiency in creating various forms of tactile graphics, as well as the impact of these images on pupils and visually weakened teachers at an Indian school for the blind.
2010	Manzeet Singh et al [33]	This research describes how to create software that converts Hindi and English text to grade 1 Braille.

2010	Sroczynski Z et al [34]	An algorithm for automatically recognizing the structure of mathematical equations recorded in graphical form is provided in this study. The method described here is based on 2D graph grammars, heuristic rules for simplifying the initial data structure, example graph grammar rules, a priority system for producing rules, and a test application that provides step-by-step inspection of the complete recognition process.
2009	Dasgupta T et al [35]	In this research a speech baseddule automatic Indian language text to Braille transliteration system is presented. The system allows a visually impaired person and a sighted person to communicate with each other.
2009	Cliffe E et al [36]	The present technology gap for students studying mathematical courses who are unable to read standard print is discussed in this paper. Higher education institutions are required to make reasonable changes to ensure that disabled students are not placed at a significant disadvantage under the modified Disability Discrimination Act (DDA).
2008	Beck-Winchatz et al [37]	They create and apply solutions to increase chances for blind adolescents in science in this study. These initiatives comprise the growth of tangible space science books and program materials, science conservatories for blind middle and high school pupils, and college practicum and mentoring programmers.
2007	Maddox S[38]	The authors picked the Duxbury Braille Translator (DBT) to create mathematical Braille from Latex files. Although they were able to make Braille lecture notes, the technique is far from trustworthy, and better software is necessary.
2007	WooseobJeong[39]	Using strength response skill, which involved in video games for ages, models of a tangible online Braille generator and

		a solid online graphical presentation for visually impaired or canopy users were built. By stirring the output Braille displays or scrolling across tactile graphical shows with a force feedback mouse, blind folks can access evidence on the web without the usage of expensive gear.
2007	Puertas et al [40]	This research presented a tactile display that consists of an electrode platform that simulates the writing/reading of Braille letters through stimulation. The skin receptors of the fingers are electrically stimulated to imitate the identical pressure and depressions as those of the paper-based counterpart information in order to experience those characters in a comparable fashion to the tactile feeling from paper material.
2002	Dickson S et al [41]	The integration of Braille text information into three-dimensional mathematical surface models. It entails manipulating a computer-specified tactile surface roughness in Computer-Aided Design, which poses a challenge to the mechanical prototyping industry's standard technical interfaces.
1998	Anupam Basu et al [42]	A innovative multiline Braille reading system based on a single low-cost personal computer is described in this paper. The method is primarily designed to meet the needs of Braille libraries, where multiple texts must be read by multiple users at the same time. Furthermore, the system can handle many documents written in different languages at the same time.

1997	P. Blenkhorn [43]	This work employs a primarily table-driven strategy to develop a system that is customizable for a extensive variety of dialects and low-coster sets. The algorithm is discussed in the framework of converting text to Standard English Braille (British), as well as the tables for this conversion.
1995	Paul Blenkhorn [44]	This paper described a method for converting Braille into print using "characters" stored in a computer. The system was designed to work with a wide range of languages and character sets.
1969	Kenneth R. Ingham [45]	This paper examines the recent trend toward instinctive Braille construction and the Institute of Technology's Research Laboratory of Electronics' expansion of a low-cost Braille conversion and adornment system.
1966	E. L. Glaser [46]	This research offered a system that used several strategies to create an accurate and reliable method for converting Braille materials to written text.

3. Current Education Scenario of Blind School: A Survey

Pre-Braille Training, Reading Readiness Test, and Reading Braille are the three stages of Braille instruction [47]. As demonstrated in fig.3.1, a kid must develop efficient tactual discrimination and synchronisation of fingers and their movements. To learn finger coordination and movement, the kid is expected to perform pre-Braille homework. The blind students successfully identify the difference between six dots during the first step of the pre-Braille training phase. As shown in fig. 3.2, the next phase is sensory training to familiarise them with various shapes such as circles, triangles, and rectangles. Reading Braille is required in the last phase. This level focuses on the recognition of dots via finger movements, as well as the identification of tiny variations between them. Braille slate Inter Point Braille Frame [48], a four-line pocket frame, and a stylus; and Brailler are all simple ways to write Braille. Braille is primarily based on printed representations that can be consumed in the latest digital technologies to provide better solutions and remove hurdles that blind people encounter in everyday life in this modern day, as well as to educate themselves for greater chances.

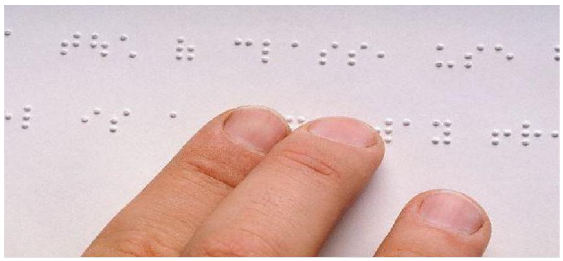
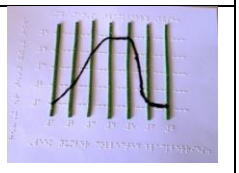


Figure 3.1: Finger movements to read Braille

Figure 3.2: Triangle shape representation using Thermopolis sheet

Current digital technologies allow for the development, consumption, and even conversion of text-based content into Braille notation, resulting in a considerably larger pool of resources. Regardless, it is much more; it is a system and an alphabet with great possibilities. Furthermore, producing and accessing Braille information was difficult and/or expensive not long ago. Table 3.1 shows the hardware tools used in Patiala and Panipat School for teaching mathematics to blind students. It has been observed, there is no particularly software tool used for teaching mathematics. Maxima, MathML [20], Math Player, Math Type - Equation Editor, Math Speak [30] are the basic software which are used to teach blind students but the main challenge in both schools is students mental level has not been trained to use such advance tools to learn mathematics.

Table 3.1: Existing Hardware tools presently employed in blind school of Patiala/Panipat

Name	Significance	Visual Representation	Name	Significance	Visual Representation
Taylor Frame and Type Sets for the frame	Used to Write Spatial Mathematics		Braille Slate and Stylus	Writing in Braille	
Abacus	Mathematics Calculations		Geometry Set – Standard and Large	Used for Geometry Constructions	
Brannan Cubarithm	Plastic Tray and Numbers to Lay Out Math Problems		Tactile Graph Paper	For graphs or spatial maths	

The academic challenges faced in the domain of discussion are based on the features including Time-consuming, Lack of teachers' skills and Lack of verbal description below as fig.3.3 (a). And features availability of tools, Lack of motivation, encouragement and motivation etc. are presented against their score are shown in the fig 3.3(b). The below data is based on the

survey of schools in the Patiala and Panipat shown in the Table 3.2.

Table 3.2: Distribution of Blind Students in Mathematics and Science Subjects

School	Choice for Mathematics	Choice for Science	Total no of Students	Number of Students in Mathematics	Number of Students in Science
Blind school (Panipat) (Haryana) till 8th standard	Compulsory	Compulsory	119	119	119
Blind school (Panipat) (Haryana) after 8th standard	Compulsory	Compulsory	31	31	31
Blind school (Bhadurgarh) (Patiala) till 8th standard)	Compulsory	Compulsory	30	30	30
Blind school (Bhadurgarh) (Patiala) after 8th standard	Optional	Optional	20	0	0

As of now the rate of taking mathematics as a subject in curriculum of 10th standard is negligible in school of India. There is shortage of teaching and learning resources available in the area of mathematics for blind students. There has also been lack of awareness and skill among teachers including special educators on the knowhow tools and technologies that can be employed for an effective teaching-learning. It is not possible to replace a teacher to serve the purpose of conceptual clarity with these tools as a book is not replacement of a teacher for sighted learners. There is need for good conceptual clarity as a blind student mainly rely on mental or the other fastest ways of resolving mathematical issues.

Fig 3.3. Analysis of Challenges Faced by Blind Students in Learning Mathematics of Two Different Schools

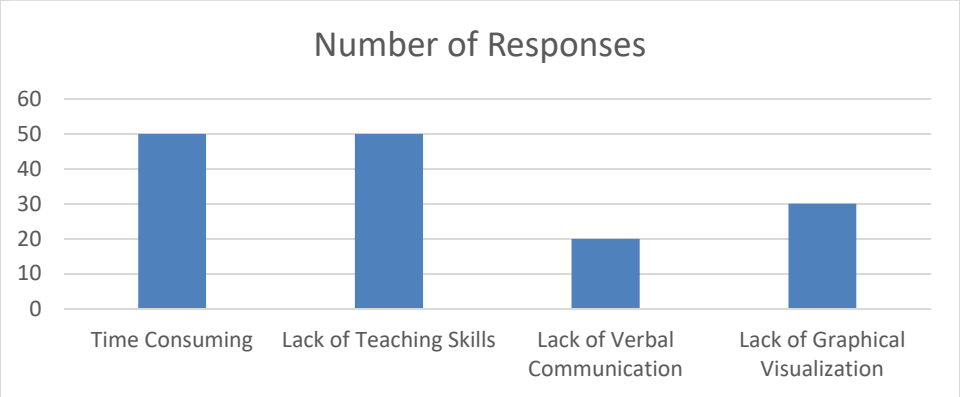


Fig 3.3 (a). Challenges Faced in Basic Mathematics

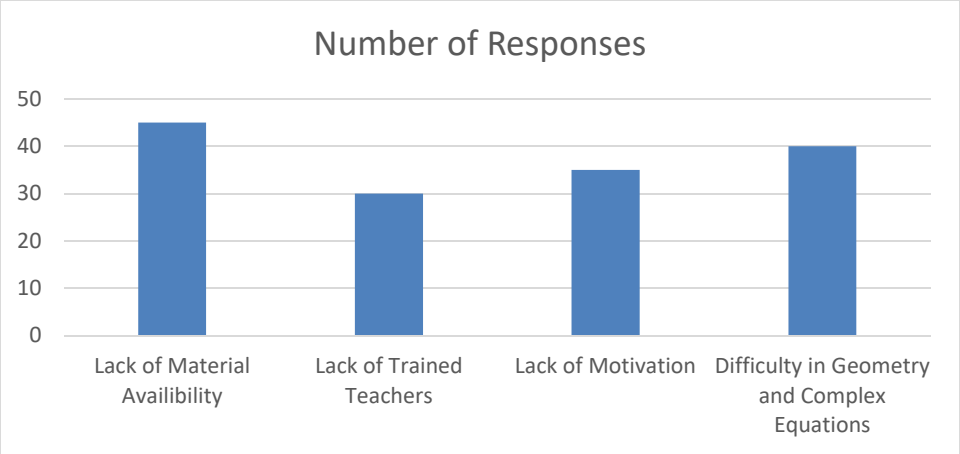


Fig 3.3(b). Challenges Faced in Advanced Mathematics

4. KEY OBSERVATIONS

The blind people can be observed everywhere in the society as they are present in large numbers. Their inability makes them get an education. They cannot cope up with the present world because of a lack of facilities. But this is not impossible. The result of the census 20ll has been taken as the base for the analysis of dimensions of disability in India. Blindness affects 18% of the population between the ages of 0 and 19 years [50]. This is the most prevalent disability when compared to others. It's challenging for blind individuals to connect with farsighted people, especially in community spaces like banks and government workplaces, where script is the key mode of communication. This problem can be solved by closing the break among the blind and the sighted, but this can only be done with the help of a support system, such as bidirectional text to Braille transliteration systems and speech-enabled edges for the visually weakened. So the concrete knowledge was gained only on realizing that there are lots of gaps that need to be addressed as early as possible. As the feel of shape and symbols are judged by putting in hands and takes a lot of extra overhead to register. This gap was detected in the collection and analysis of the few samples of students and working professionals from a school.

(i) As observed in Punjab School Education Board the mathematics subjects for blind children are optional after 8th standard and another board is compulsory till the 10th standard. Teaching mathematics to blind children is a more challenging task as compared to other subjects. Due to this reason, a mental barrier is automatically generated in the mind of teachers and students simultaneously. So most of the students drop mathematics after 8th or as it becomes optional

(ii) There is a lack of ground-level work in the field of mathematics when the following parameters were considered of prime importance: Mathematical shapes, symbols, and Mathematical equations i.e. the factor of recognizing shapes: circles, triangles, squares; symbols: alpha, beta, sigma, pi, etc. and hence trigonometry equations [17].

(iii) Balsa foam cubes with few inches in diameter have been taken for six models. The help of three-dimensional computer images have been selected to finalize the shapes and position the equations before the bronze sculptures are cast, a durable material that can withstand extensive handling material has been dropped when needed. As it's an opportunity to fill the gap between living experience and science, mathematics, and technology through sculpture. As it is generally seen that Taylor frame, Geometry kits are primarily deployed for primary level mathematics but with the challenge of explaining all symbols as all are not included in this frame and result is knowledge impartment of limited symbols possible only. Though, in general, thermocol and its respective texture have certain advantages but at the same time having challenges in

terms of preparation to be made in advance by teachers [51] which is also time-consuming.

(iv) Teaching Learning Methodology is another concern for enhancing the activities list. At the basic level, a teacher's first most difficult challenge towards blind children is to tell them how to learn the subject. As compared to normal students teaching blind students is more challenging and time-consuming like Just Conveying a single shape to blind children. Firstly the teacher has to create the image of the shape to be taught in blind children's minds. it could be made possible on thermocol or any inbuilt frames. But in reality, it becomes very difficult when there are more varieties of the same shapes and symbols it becomes more difficult for the teacher. If a teacher has to clear the concept of polygon practically it is very difficult to create the same image in the mind of students. In the same way, they have a problem with higher mathematics like trigonometry and integration equations.

(v) The majority of blind people's systems are written in foreign languages such as English, French, German, Spanish, Portuguese, and Swedish. Duxbury programmer, which is not open source and costs a hefty $695, can still fail to create shapes as envisioned for some. Although versatile geometry kits are available, there are fewer and fixed permutations to choose from. Because Indian scripts differ from that of European or American languages, various guidelines are desired to transcribe them into Braille [33].

(vi) Career Consultation regarding mathematics or in any other subjects should be provided especially to the blind students at a regular interval of time from very basics so that they would aware of every subject that can mold their careers towards a specific field.

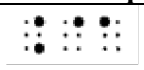
4.1 Challenges

In India and across the world, many visually impaired people showed a passion for mathematics and thus met with success in their respective fields [52]. Basic mathematics education is found very hard and difficult by blind people who are part of primary and secondary education. Blind people in India are still out of this right to basic education, Due to the lack of awareness over the years which subsequently hinders their career choices and career growth. Generally, blind students drop mathematics after 8th standard where they are allowed and in other cases they find themselves to choose a career in the field of mathematics after 10th standard because of the increasing difficulty level in mathematics and lack of teaching aids. As a result, the choice of mathematics is ruled out by most of the blind students

(i) There is a lack of Ground-level work in the field of mathematics when the following parameters were considered of prime importance: Mathematical Shapes, i.e. the factor of recognizing Shapes, Circles, Triangles, Squares can be leaned by heart and visualized only to some extent just with the touch enabling method. But it becomes difficult to recognize the polygon with more sides and also to distinguish between the regular polygon and irregular polygon becomes irrelevant too. So mastering mathematics is found challenging for blind children [53].

(ii) Mathematics has been taught by Nemeth code to blind children. In Nemeth code, every shape and symbols have a Braille code but it does not learn to children how to sense, feel and recognize the actual shape means blind children know that hexagon's Braille code but in actual he/she does not recognize the actual shape of a hexagon.

Table 4. Symbols and Shapes representation of Braille through Nemeth Code

Name	Symbol	Braille Equivalent	Name	Symbol	Braille Equivalent
Alpha	α		Circle		
Beta	β		Triangle		

(iii) A very hard thing to imagine for people with no sight problems is what blind people think about mathematical symbols [54]. Because they never saw how a theta or a gamma looks like, they simply cannot imagine how these symbols are, blind people learn code of symbols In the same way, they remain unable to learn trigonometry as they find themselves unable to imagine and visualize the shapes, symbols, and equations like $\cos\alpha + \cos\beta = 2\cos\frac{1}{2}(\alpha+\beta)\cos\frac{1}{2}(\alpha-\beta)$.

5. CONCLUSIONS

This research is proposed to be a humble contribution to enable blind people to explore more possibilities in the field of mathematics. The current study has explored the braille reading methods and different software that helps blind people in gaining an education. The literature shows that less amount of work has been performed on mathematics education for the blind. The key challenges, observations and future scope for mathematics have been discussed in detail in the current study.

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