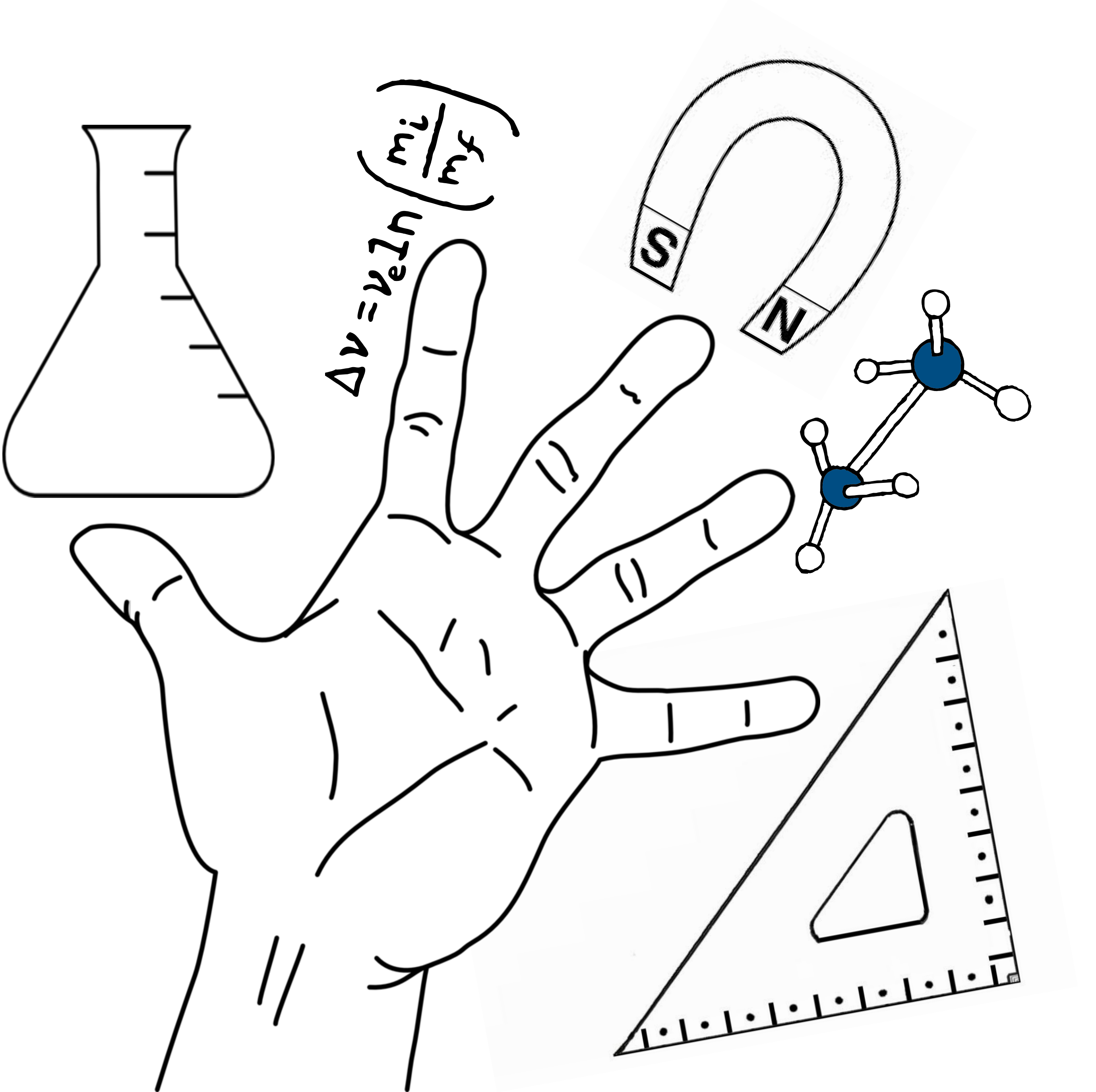
Numbers and Reactions

A Report on Mathematics and Science Access for the Visually Challenged

by

The Xavier's Resource Centre for the Visually Challenged (XRCVC)



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A Report on Mathematics and Science Access for the Visually Challenged

Based on the research conducted by:
The Xavier's Resource Centre for the Visually Challenged (XRCVC)

As part of the **Vision for India (VFI)** Project of the **Tech Mahindra Foundation**

ISBN : 978-81-929012-0-6

*“Do not worry about your difficulties in Mathematics,
I assure you that mine are greater.”*

- Albert Einstein

PREFACE

The three R's to learning – Reading, Writing and Arithmetic — have been long considered the corner stone to education. Creativity and analytical thinking often associated with mathematics and science learning is an integral part to formative education. In the increasingly competitive world of education and work, mathematics has become a part of testing and environment even in traditionally non-scientific areas.

Whilst mainstream education has always focused on the three R's of learning, education in the world of the blind and low-vision, especially in India, has often left out the third R—Arithmetic — within education. This has often been due to myths and misconceptions.

It is essential that the pool of talent latent in the visually challenged population in India should not go untapped and consequently wasted. It is essential that every blind/low vision child should get the necessary opportunity to, if they so wish, explore science, technology, engineering and mathematics (STEM subjects). It is STEM that forms the base for many of humanity's major advances and given the right inputs, opportunities and pedagogy, the visually challenged students can perform on par with their sighted counterparts. Today technology has advanced to make large leaps for the blind and low vision persons towards independent living and education. The same holds true for learning of mathematics and science as well. However despite the crying need coupled with possibilities, the ground realities remain very different. We oftentimes have to face the painful situation where students have to make strenuous efforts at learning fundamental mathematical concepts as part of their preparatory work for competitive exams during or soon after their graduation simply because the line of least resistance (continuing with only Std 7 level mathematics) was resorted to only because people were not aware of the alternatives.

The ***'Numbers and Reactions'*** project and report is an attempt to understand the reason for the ground reality lacunas, identify possibilities and commence planning interventions to bridge the gap. This effort is to make a beginning for inclusive mathematics and science education in India for the blind and low-vision persons in a proactive manner.

The XRCVC would like to extend heartfelt gratitude and thanks to the Tech Mahindra Foundation for the funding support extended under its Vision for India (VFI) project. Without this, the project would never have taken off. We also acknowledge other organisations and individuals whose involvement has helped ensure the success of this research project. A special mention needs to be made of Saksham Trust, New Delhi, for partnering to enable this initiative to take off and all the other individuals and organizations that actively participated in the survey and provided valuable inputs.

We hope that this report will prove to be a useful starter kit to anyone interested in inclusive mathematics and science education for the blind and low-vision in India.

Dr Sam Taraporevala
Research Director
December 2013

Project Implementer

Xavier's Resource Centre for the Visually Challenged (XRCVC), St. Xavier's College, Mumbai (www.xrcvc.org)

The XRCVC is a state of the art support and advocacy centre for persons with blindness and low vision. It is a department of the St. Xavier's College, Mumbai, India, and works actively in the areas of providing Direct Support and Training Services to blind and low-vision persons, Awareness Generation and Advocacy Initiatives.

The XRCVC works actively towards creating an inclusive environment both at the micro and the macro levels. Some of the key areas of its advocacy initiatives lie in the field of Print Access, Financial Access, Education Access and Independent Living.

The Maths and Science Access Project is a key advocacy, awareness and direct support initiative at the XRCVC within its Education Access framework. The XRCVC strongly believes that an active three-pronged project aiming at creating awareness, making suitable changes in systems and rules and availability of effective training and content in the area of maths and science education for blind and low-vision persons is the need of the hour. The '***Numbers and Reactions'*** research was undertaken to lay the foundation of this project.

Project Team

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CHAPTER 1: INTRODUCTION

The visually challenged in India have been traditionally viewed as not competent to study the Mathematics and the Science faculties. Simultaneously, there have been many visually impaired persons in India and overseas who have shown a penchant for the sciences and consequently met with success within their respective fields. Basic Mathematics and Science education is crucial to primary and secondary education. Because of the lack of awareness over the years, the visually impaired in India, even today, are being left out of this right to basic education which subsequently hampers their career choices and career growth.

It is this gap between the need and reality that drove the Xavier's Resource Centre for the Visually Challenged (XRCVC), Mumbai (www.xrcvc.org) in partnership with Saksham Trust, New Delhi (www.saksham.org) to initiate a joint research project in the area of Mathematics and Science Access for the blind and low-vision under the Vision For India (VFI) platform of the Tech Mahindra Foundation.

The Project was undertaken to meet two key Objectives:

Objective 1: To research and identify the most appropriate teaching-learning process and content to impart Mathematics and Science education to varied groups of visually impaired students (totally blind, low -vision, child and adult learners)

Objective 2: To develop, create, produce and set up a distribution channel for educational content and teaching-learning aids for mathematics and science at various levels

The XRCVC undertook work under Objective 1 whereas Saksham Trust undertook work under Objective 2. The current report outlines the XRCVC's work under Objective 1 and its outcomes, outlining the future course of work in this much required area of education access.

XRCVC's Research Framework

As outlined above, the XRCVC's key research objective was the following:

- ***To research and identify the most appropriate teaching-learning process and content to impart Mathematics and Science education to varied groups of visually impaired students (totally blind, low-vision, child and adult learners***

The Key Activities identified for the research included the following:

- To undertake research on existing pedagogies within Mathematics and Science teaching for the visually impaired and creative teaching pedagogies. To be done in collaboration with strategic tie-ups with experts in the field.
- To develop a catalogue of existing content and teaching-learning aids within the field of mathematics and science that can be readily available to students and teachers alike.
- To identify gap areas in pedagogy and content that needs to be worked at.
- The research and need identification to be done for the varied range of learners-totally blind, low vision, children and adults.

Expected Outcomes of the research included the following:

- A holistic understanding of the ground-level needs and methods for mathematics and science teaching for varied groups of visually impaired students. The same to be made available for sharing in the form of a compilation.
- An action plan for the nature of teacher training modules and direct teaching modules for visually impaired persons to be made ready.
- Catalogue of existing resources, aids and their availability location.

Scope:

The research aimed to focus on getting a more detailed perspective for the Indian scenario. International secondary research was undertaken wherever possible to supplement understanding of best practices and create a holistic understanding of the subject. User-level testing and data collection has been limited to Indian respondents.

Research Method:

The Research was conducted at two levels, for which different methodologies were used.

Level One – Primary Data Collection: For this, Internet/Telephonic/In person Survey method was used to collect data from a purposive random sample of totally blind and low-vision men and women, sighted teachers and professionals working for the blind in the area of maths and science education in India. The sample size is 45.

Weighted Average and Percentages have been used to analyze the primary data collected.

The questionnaires used for the survey are attached as **Annexure A and B**

The sample does not claim to have statistical confidence, the survey has been an exploratory process to gauge and identify ground level reality in mathematics and science teaching-learning in India.

Level Two–Secondary Data and Testing. For this the following was undertaken:

- An extensive literature review of national and international Best Practices in teaching and learning of mathematics and science to blind and low-vision persons.
- An extensive compilation of Assistive Technologies (AT) and other Teaching-Learning Aids (TLA) available and used for mathematics and science learning both in India and internationally and user-level testing by Indian users for some of the key technologies.

CHAPTER 2: MATHEMATICS AND SCIENCE IN THE WORLD OF THE BLIND AND LOW-VISION: THE INDIAN REALITY

The XRCVC's Primary Data collection aimed at capturing the ground level mood and reality of mathematics and science teaching and learning experience amongst the blind and low-vision persons in India.

The level of mathematics and science teaching and learning in India for the blind and low-vision is at a very nascent stage currently. A large number of students tend to drop out of studying these subjects at Class 8^{th} in schooling as various state boards have the provision for them to take replacement subjects. Although this is an optional choice, over a period of time it has become the default choice due to paucity of services and resources to make these possible and apprehensions amongst students, teachers and parents alike.

Hence for the purpose of this study a purposive random sample was selected of students and professionals who are engaged in at least some degree of teaching and learning of mathematics, in order to understand the ground-level user needs and challenges of this area in India currently.

The sample does not claim statistical confidence, nor does it claim to have covered every mathematics and science teaching-learning initiative within India. It is just an attempt to make a beginning to start building ground-level understanding so that intervention in the area of inclusive mathematics and science education could take off at a higher level.

The data below is presented under 4 sections:

Section I: The Research Sample
Section II: Mathematics and Science Learning Level
Section III: Mathematics and Science Teaching—the 'HOW' of Learning
Section IV: Mathematics and Science Teaching—the Pedagogical Challenges

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Section I: The Research Sample

The Sample size for the research was **45**. The demographic distribution of the sample along with the nature of vision loss and nature of onset of blindness amongst the blind and low-vision sample group is as under:

Table 1: Distribution of nature of respondents

Nature of Respondent	Number	Percentage
Blind and Low-Vision	32	71
Not Visually Impaired (Teachers/Professionals	13	29
Total	45	

Table 2: Distribution of nature of Blindness amongst Respondents

Nature of Blindness	Number	Percentage
Totally Blind	19	59
Low-Vision	9	28
Data Not Available	4	13
Total	32	

Table 3: Distribution of Nature of Onset of Blindness amongst Respondents

Nature of Onset	Number	Percentage
Born Blind	10	31
Later Onset	12	38
Data Not Available	10	31
Total	32	

Because of the limitation of telephonic interviews as also varied learning levels, complete data across all questions of inquiry could not be procured from all respondents. Hence, for Section III, percentages have not been used — rather actual numeric representations have been used to present incidence rather than comparative percentages.

Section II: Mathematics and Science Learning Level

The profile of blind and low-vision respondents of the group is spread across various educational boards. The first level of analysis has been to identify the level of mathematics and science that respondents study. This forms the base level of understanding of what level of learning is taking place at the ground level. The data is presented below:

Table 4: Distribution of Respondents across Educational Boards

Education Boards where the visually impaired studied/study	Number	Percentage
State Boards	24	75
Central Board of Secondary Education (CBSE)	3	9
ICSE	1	4
Data Not Available	4	12
	32	

Table 5: Level of Mathematics Learning amongst Blind and Low-Vision

Till what Level has Mathematics Been Studied	Number	Percentage
Till 10th Std	8	25
Till 12th Std	3	9
Till Graduation	2	6
Till Post-Graduation	2	6
Studied only as Adult Learner for Competitive Examinations	1	3
Still In Lower Classes	1	3
Data Not Available	6	19
	32	

As reflected in the data above, majority of blind and low-vision students do not pursue learning of mathematics at the higher level. Besides further analysis of the data reveals that there is a disparity in educational boards for learners to continue at least Std 10 mathematics as against doing mathematics of a lower grade. Students in the Tamil Nadu State Educational Board and the Andhra Pradesh State educational board tend to continue mathematics up to Std 10 whereas majority of students in the Maharashtra State educational board tend to take up concessional mathematics. This could be because of concession rules more readily available within certain boards as also the regional preference for certain subjects.

Table 6: Level of Science Learning amongst Blind and Low-Vision

Till what Level has Science Been Studied	Number	Percentage
Till 10th Std	13	41
Till 12th Std	4	13
Till Graduation	0	0
Till Post-Graduation	1	3
Studied only as Adult Learner for Competitive Examinations	1	3
Still In Lower Classes	1	3
Data Not Available	6	19
	32	

As reflected above students are able to continue science learning till 10th std. However hardly any students pursue the same at the higher education level.

Comparing the levels of mathematics and science learning, it reflects that higher levels of students are able to pursue science up to Std 10 as compared to mathematics. However a higher proportion of students tend to continue mathematics at the graduation / post graduation level compared to science.

Section III: Mathematics and Science Teaching—the 'HOW' of Learning

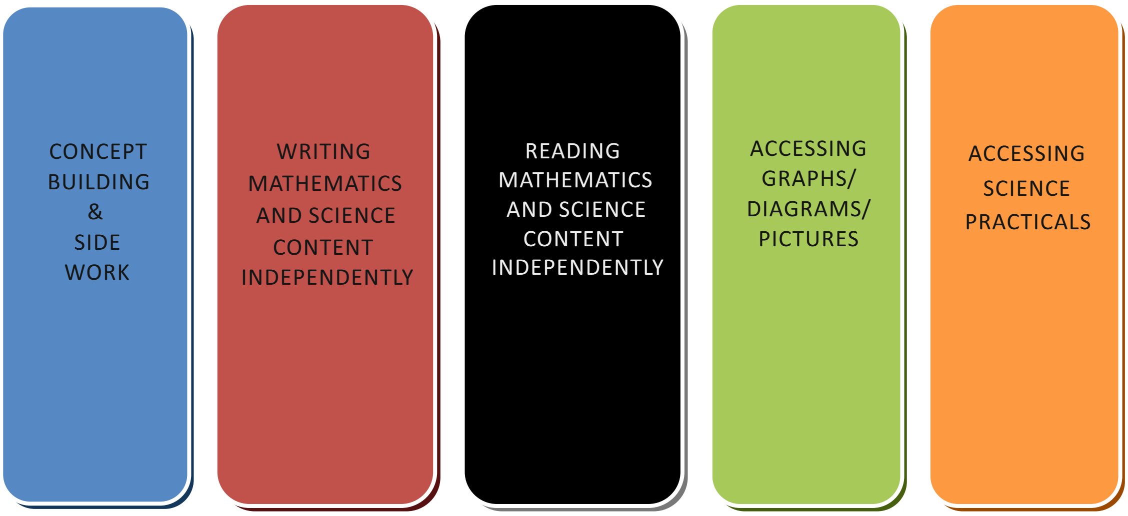
There is always a 'how' of learning any subject, the tools and raw material required for learning. The key to learning any subject involves three key aspects: Reading, Writing and Understanding.

The challenge to teaching and learning mathematics and science for the blind and low-vision has been in the areas of having access to the spatial, diagrammatic and practical components of mathematics and science, and having access to reading and writing mathematical and scientific content independently.

Lack of clarity, resource availability and awareness about the above has lead to myths over the years that these subjects are out of reach for the blind and low-vision.

Mathematical and Scientific aptitude is sight independent. There are many examples of persons who, in the absence of resources and teaching support, have been able to learn and excel at these subjects. What the research aims to do is identify the methods and resources currently being used in India at the ground level to help us understand the missing gaps and fill the same with Best Practices and the advantages provided by latest technologies.

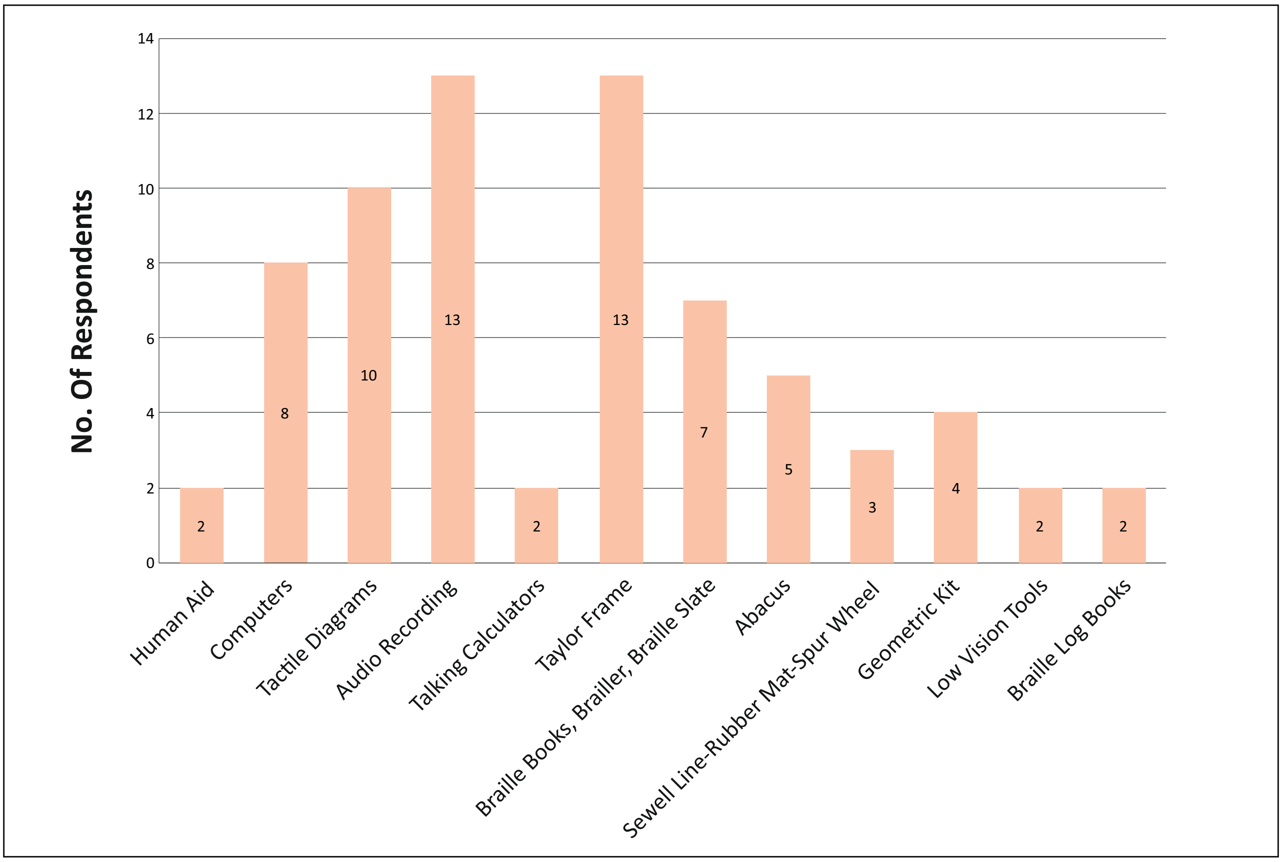
For the purpose of data presentation in this section as also subsequent secondary data, a FIVE PILLAR approach to analysis of the 'how', will be approached. These constitute the raw material required to study, teach and learn mathematics and science. Analysis is divided in the following verticals:



Concept Building and Side Work:
The first step to learning mathematics and science is building concepts. To understand mathematics you must be able to understand the spatial relationships of mathematical equations and solve the same. To solve mathematics equations you also need to calculate and remember. For geometry one begins with being able to learn and understand constructions and many more.

When we explored with respondents, both students as well as professionals working in Maths and Science Education, of what tools and aids are used to study maths and science, the following was found:

Figure 1: Equipments Used for Teaching/Learning Mathematics



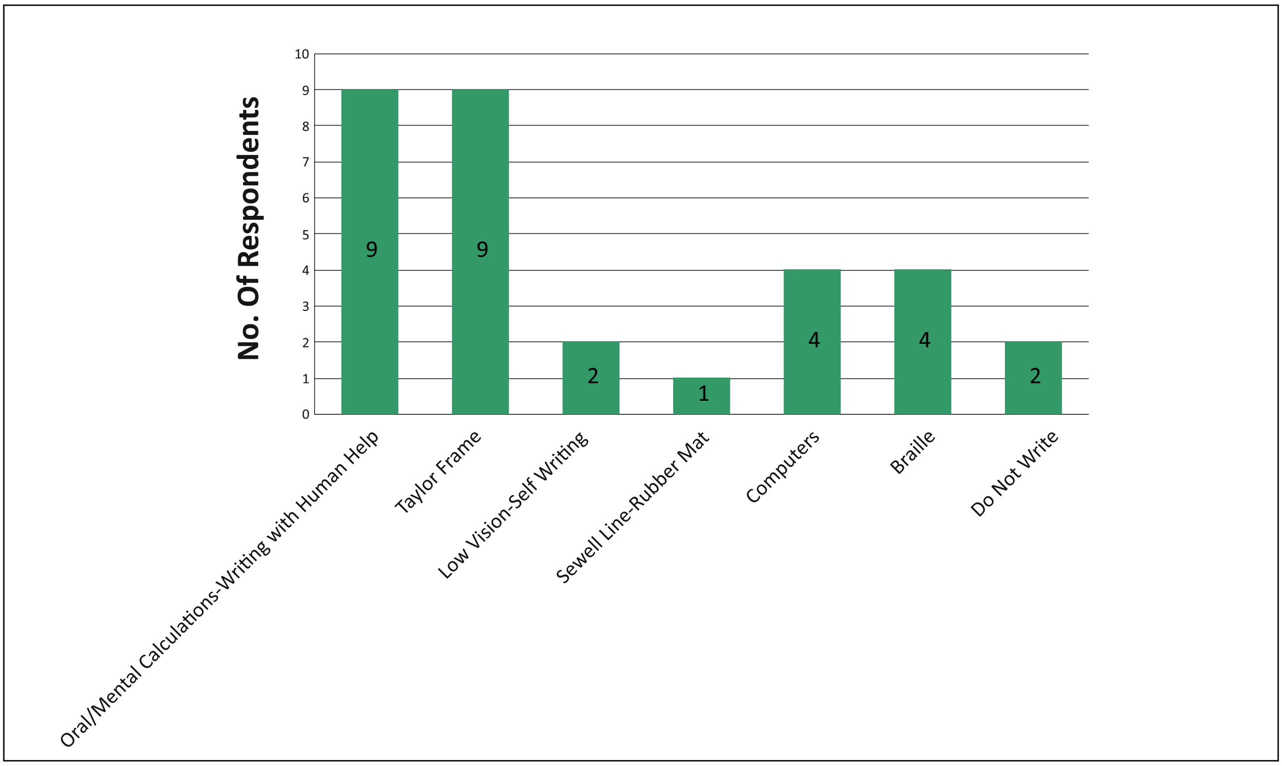
As illustrated from the figure above, currently on the ground level, Audio recording and the Taylor Frame are the most popularly used methods and tools for teaching and learning. Whilst computers are being used, specialized maths and science assistive technologies have not yet made their advent at the ground level. Respondents using Braille also have noted that they are using the same only for basic level maths. Nemeth code is not being used for higher level mathematics. Within India the Braille Mathematics Code for India is the popular code used, which is essentially a condensed version of the complete Nemeth Braille Code containing up to school level symbols.

Also in terms of inquiry on how these equipments are accessed, majority of the respondents stated that the same are personally owned and purchased from NGOs and organizations. There was only a very small portion (3 respondents) who stated that the educational institute arranged for the same through NGOs for the student.

Writing Mathematics and Science Content Independently:

Whilst screen readers and magnifiers have become an inherent aspect of independent writing for most blind and low vision persons across India in a manner that the written work can be stored and is instantly accessible to sighted teachers, colleagues, friends; in the area of writing mathematics and science equations, the same screen readers have not been as useful. **T**his gap has left independent writing work of mathematics and science a challenge to cope with. Work done with the Taylor Frame and other similar writing devices traditionally used by the blind and low vision do not offer the feature of storing the work. Braille work is not instantly accessible to the sighted, unless on electronic Braille systems – which are financially out of reach for a majority of blind and low vision in India. And the mainstream screen readers have yet not come up to the mark for seamless access for mathematics and science equations. Given this, the current ground level data revealed the following:

Figure 2: Methods used for Writing Mathematics and Science Equations



As illustrated above, currently there is a high reliance on human help to write maths and science equations along with use of the Taylor Frame. Both these have their limitations of not permitting independence as also not permitting access to the handwritten work or work done on Taylor Frame for later recall and revision.

Reading Mathematics and Science Content Independently:

Having independent access to reading mathematics and science content remains a challenge for the same reason as writing does at the ground level. This area has been explored at two levels. Firstly, in what formats is mathematics and science material available. And secondly, in the absence of accessible material, how are end-users accessing mathematics and science content. Data on both these is presented below.

Figure 3: What Formats are Books Available in for Mathematics and Science?

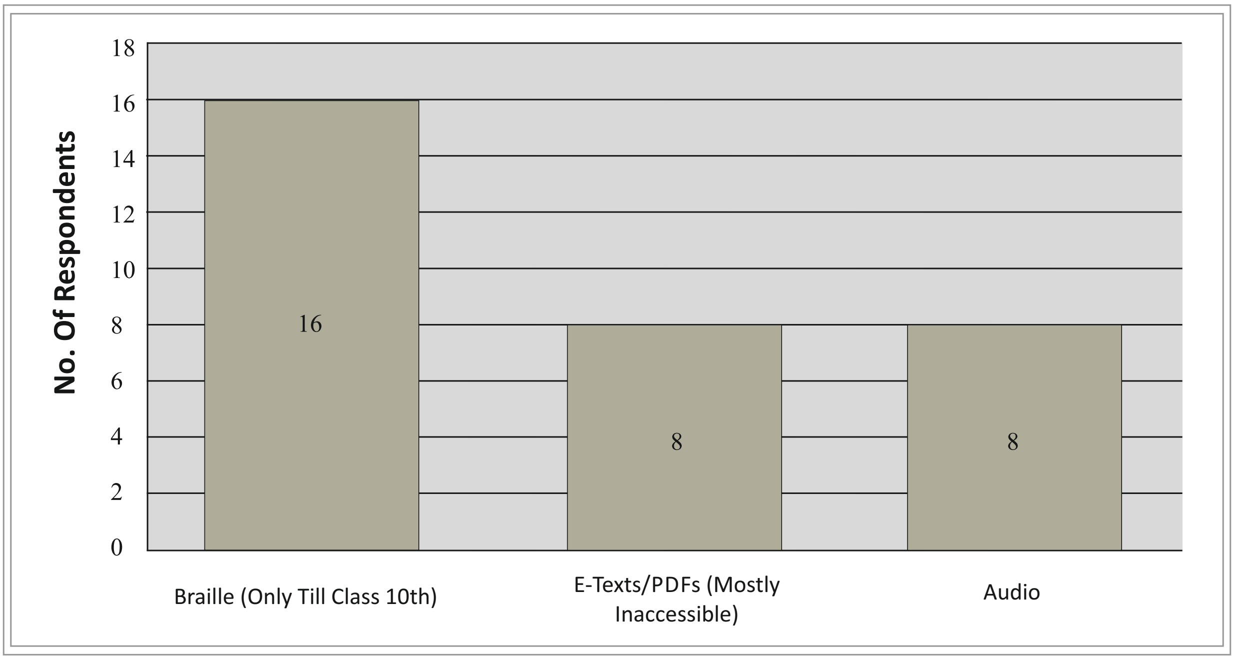
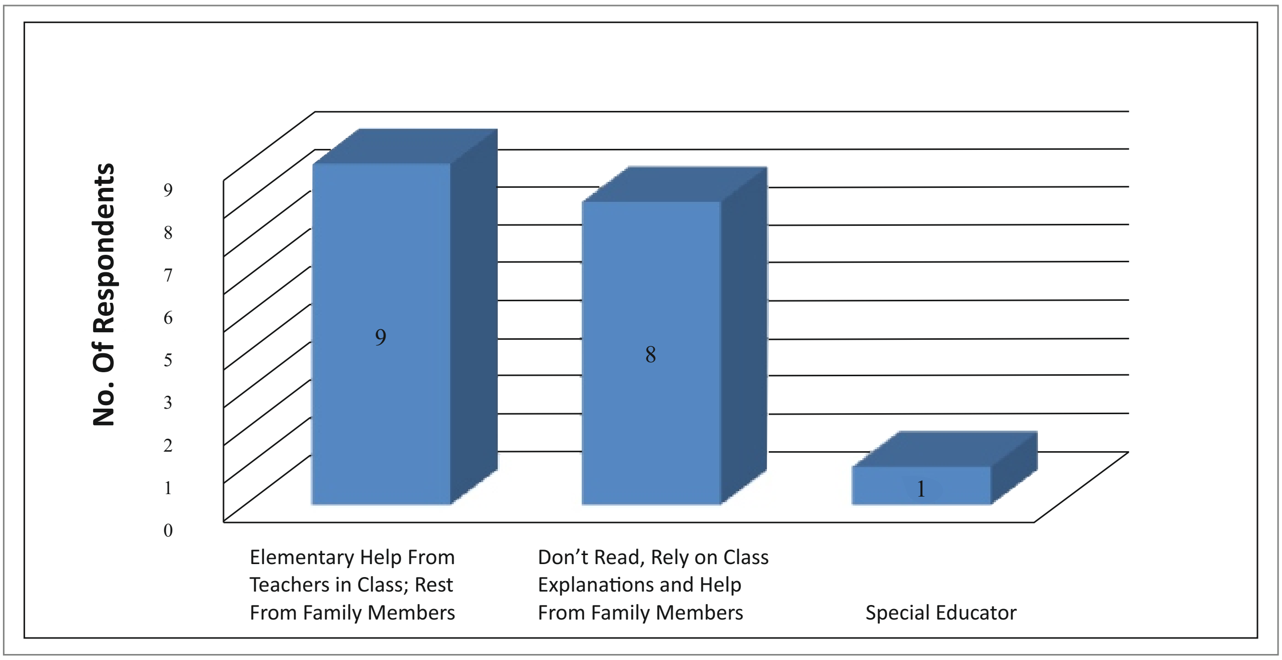


Figure 4: In absence of Accessible Books, how are mathematics and science content accessed?



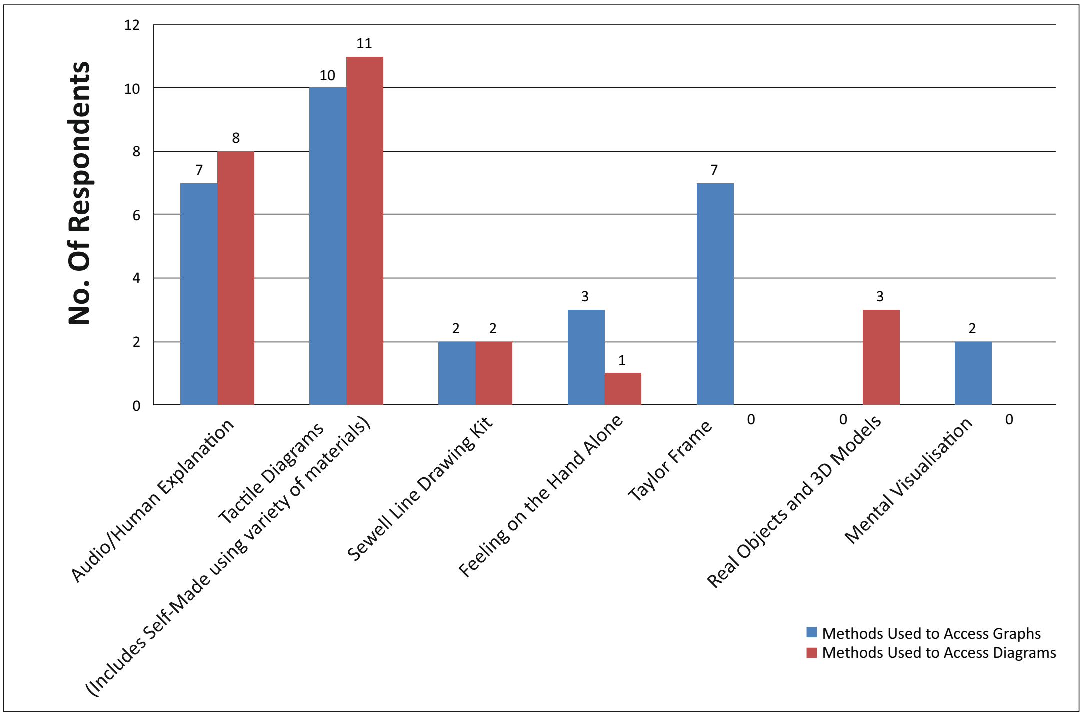
The data above reflects a clear paucity of accessible content available at the ground level. Braille content is largely available only up to Class 10^{th} and the e-content available is not fully accessible. For higher level mathematics and science audio seems to be the only option being exercised.

Further what is extremely stark is that in the absence of accessible content, students are either relying purely on class explanations and learning or on help from family members. Professional support in this area is almost non-existent.

Accessing Graphs/Diagrams/Pictures

The other key aspect of mathematics and science learning which has been regarded as primarily visual and hence out of access for blind or low-vision students has been the area of graphs, diagrams and pictures. Whilst graphs and diagrams both constitute visual elements, and methods to access them might overlap, conceptually they are different. Hence for the purpose of analysis they have been treated separately to ascertain if any differences emerge in the way students access the same. The data related to the same is presented below:

Figure 5: Methods Used to Access Graphs and Diagrams



The data presented above reflects the interesting difference in methods used to access graphs which are essentially 2D in nature, whilst diagrams are often 2D representation of 3D objects. Whilst the Taylor Frame (along with use of rubber bands around the Taylor Frame types) is a popular method for accessing graphs, the same is not at all used for accessing intricate diagrams. Similarly, plain mental visualization whilst used for understanding graphs is not used for understanding diagrams, simple drawing on the hand is used more often for graphs rather than diagrams. Similarly 3D models and real-life objects are considered a useful tool for studying diagrams but not used for studying of graphs.

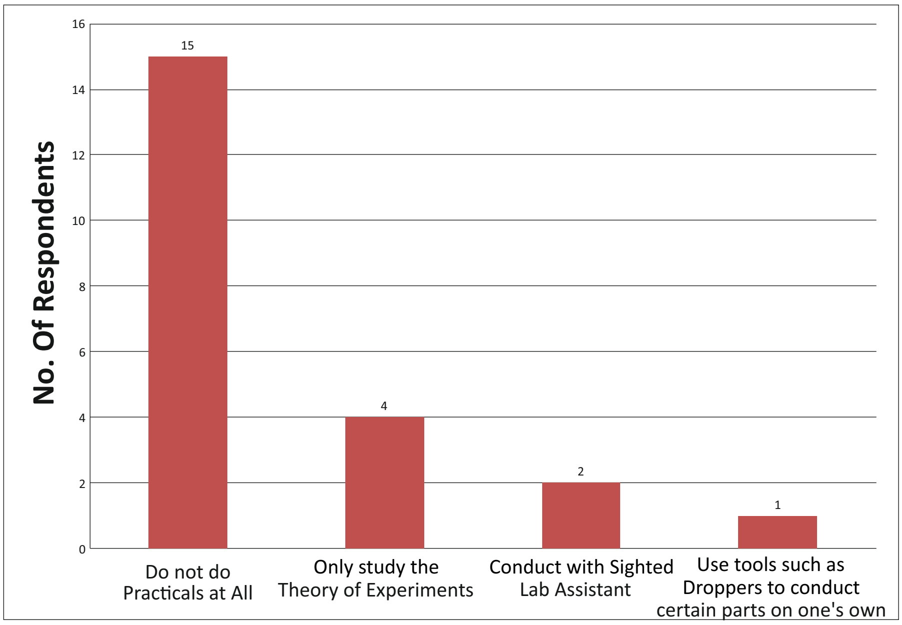
Further, important point to note from the above data is that whilst tactile diagrams are used extensively, they are rarely used in the absence of accompanying human/audio explanations. This is extremely critical to note in creation of accessible content for graphs and diagrams. Also, on the ground these tactile diagrams often constitute individually made diagrams made by a variety of innovative resources — such as sticks, clay, thread, wiki sticks, gel , etc).

The above data therefore clearly highlights the difference in accessing visual content related to subjects which are inherently 2D in nature over a 2D representation of an inherently 3D object. The latter benefits far more with a 3D equivalent learning tool. Also the data clearly highlights that tactile diagrams and models almost always need to be accompanied with their explanations and cannot be used as standalone learning aids.

Accessing Science Practicals and Lab Work

One key aspect of studying of science subjects is the lab work and practicals that are an inherent aspect of all school and post-school studies of science subjects. One of the key reasons why the blind students have been traditionally regarded as not being able to pursue the science fields is because of doubts and concerns of how a blind student will handle laboratory apparatus and conduct the required experiments. The data below shows the current scenario on the ground related to how blind and low-vision students access the same.

Figure 6: How are Science Practicals and Lab Work Handled by Blind and Low-Vision Students?

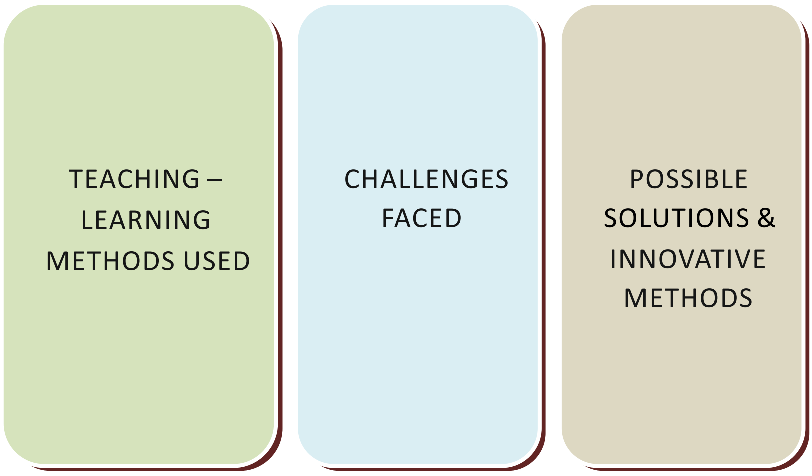


The above data clearly highlights the big gap in science education at the ground level. Majority of respondents do not study practicals at all, leaving a big gap in quality learning of the sciences. Much is left to be desired in making this area of learning accessible for the blind and low-vision students with the use of technology available for the same as also encouraging methods of using lab assistants and simple tools like droppers and other tactile markings on laboratory apparatus to make the same accessible to students.

Section IV: Mathematics and Science Teaching—The Pedagogical Challenges

The above section has outlined the ways that the 5 critical components of concept building, reading, writing, accessing graphs & diagrams and conducting practicals in mathematics and science are handled at the ground level currently in terms of tools and methodologies used. These however culminate in the overall teaching and learning of mathematics and science at the ground level.

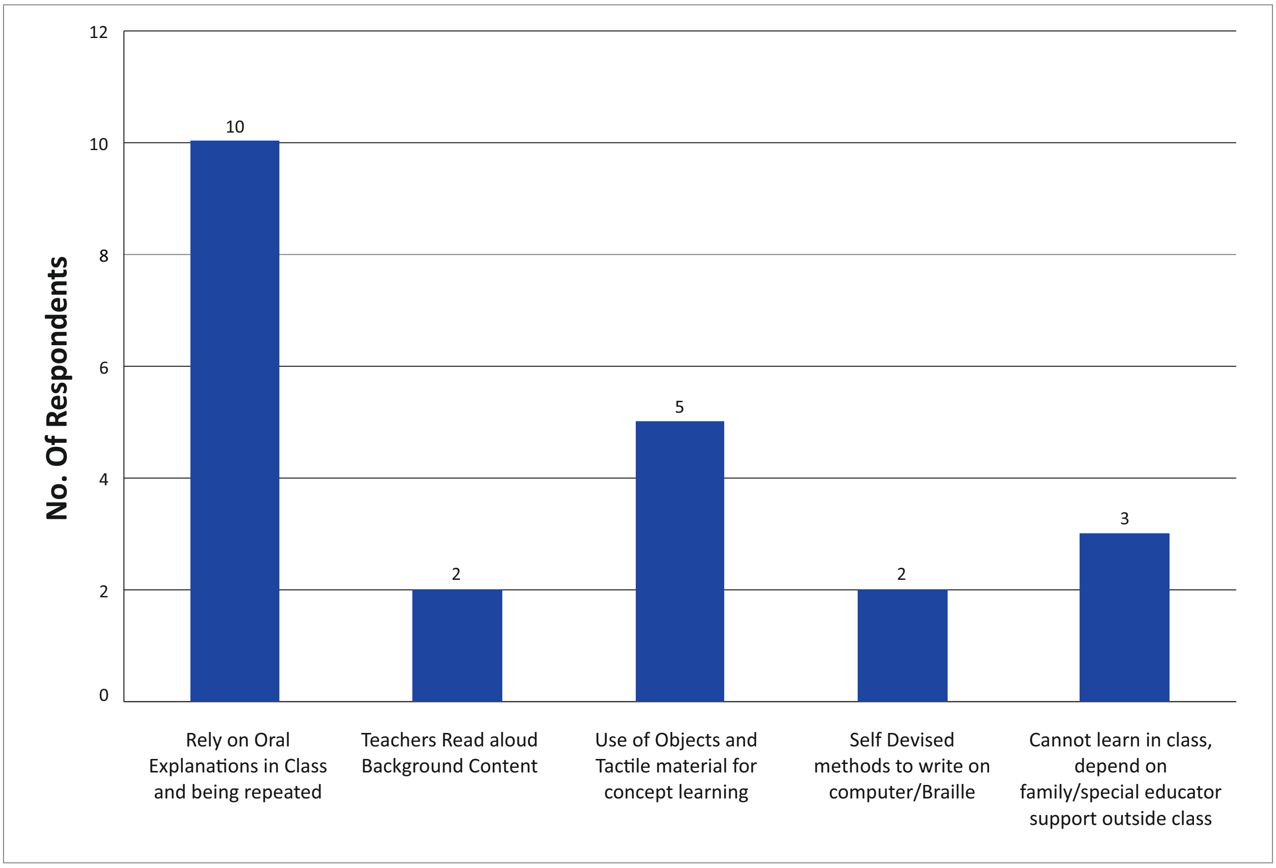
This section seeks to outline the key pedagogical concerns that are faced by students and teachers alike in studying mathematics and science and the techniques being currently used to overcome the same. This section will outline the data within three broad areas:



Teaching-Learning Methods Used

Whilst the earliers section has outlined the specific tools or techniques used in tackling specific component of the teaching-learning process, when respondents were asked what are the techniques they employ and depend on for learning mathematics and science material in school education, the data revealed the following:

Figure 7: Methods relied upon for teaching-learning mathematics and science



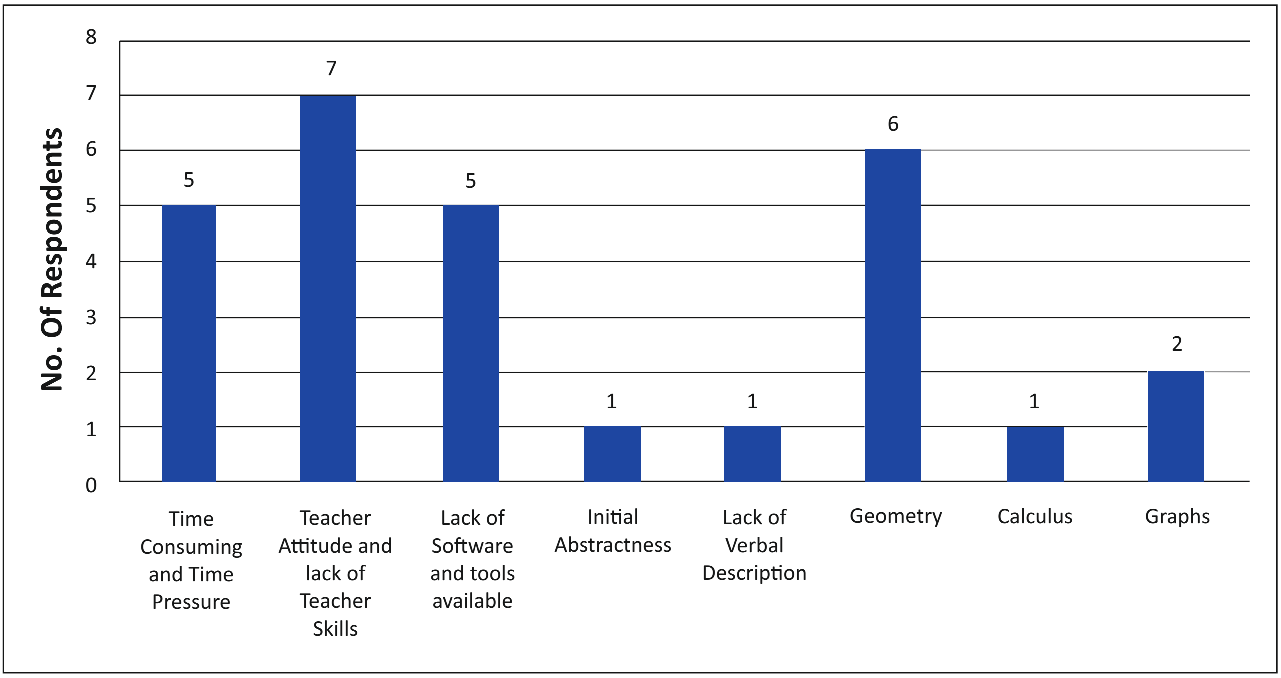
The above data reveals that as of now the maximum reliance is on oral explanations and the same being repeated for reinforcement for learning of mathematics and science. In the absence of adequate classroom reinforcement there are students who solely rely on out-of-class support, either through family members or special educators, for learning. Students also tend to depend on self devised methods in absence of structured methods available to them for learning.

Challenges faced in Learning Mathematics and Science

Based on the various methods and tools used to teach and learn mathematics currently, when respondents were asked what are the biggest challenges they face in studying and learning of these subjects a range of concerns have been found. These are presented in three different aspects — specific challenges for mathematics and science and overall concerns.

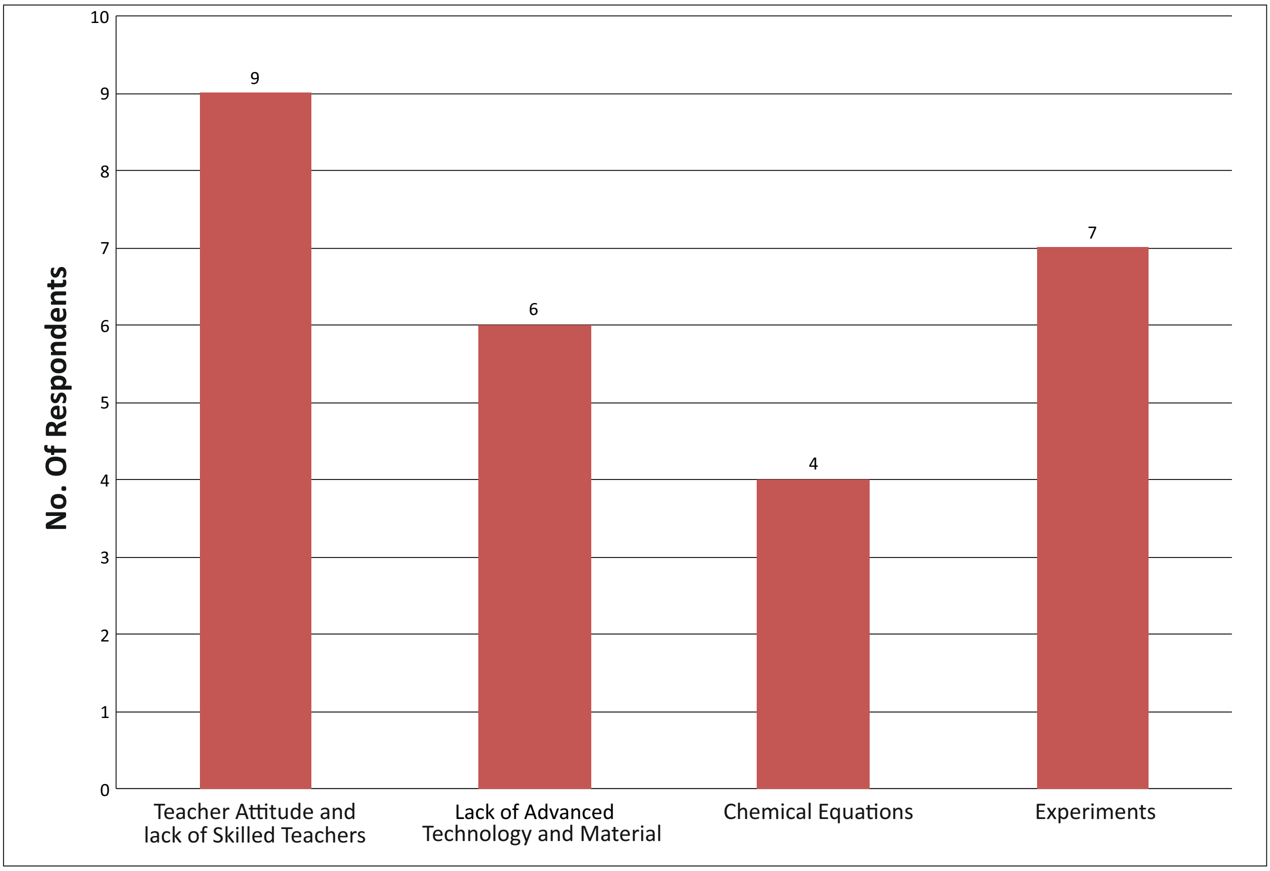
Specifically in the case of mathematics they are of study and other challenges listed are as mentioned below

Figure 8: Key Challenges faced in Studying of Mathematics



The Key challenges faced in the area of sciences included the following:

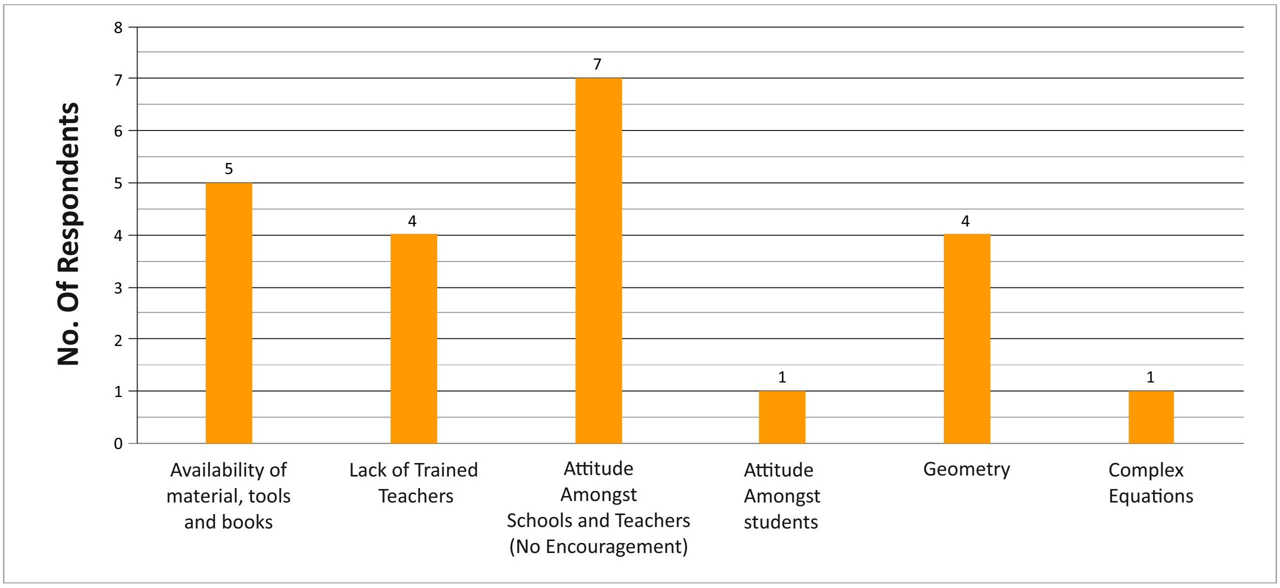
Figure 9: Key Challenges faced in Studying of Science



Based on the above data both sets reveal that the biggest challenge is in the area of teacher attitude and lack of skilled teachers and lack of technology, tools and resources. In addition to these two key areas the key subject areas found to be challenging are geometry and calculus for mathematics, and chemical equations and experiments for science.

Having seen this, when asked what are considered by the respondents to be the “Biggest Hurdle” in studying of mathematics and science, the respondents had the following to share.

Figure 10: Biggest Hurdles faced in studying of Mathematics and Science



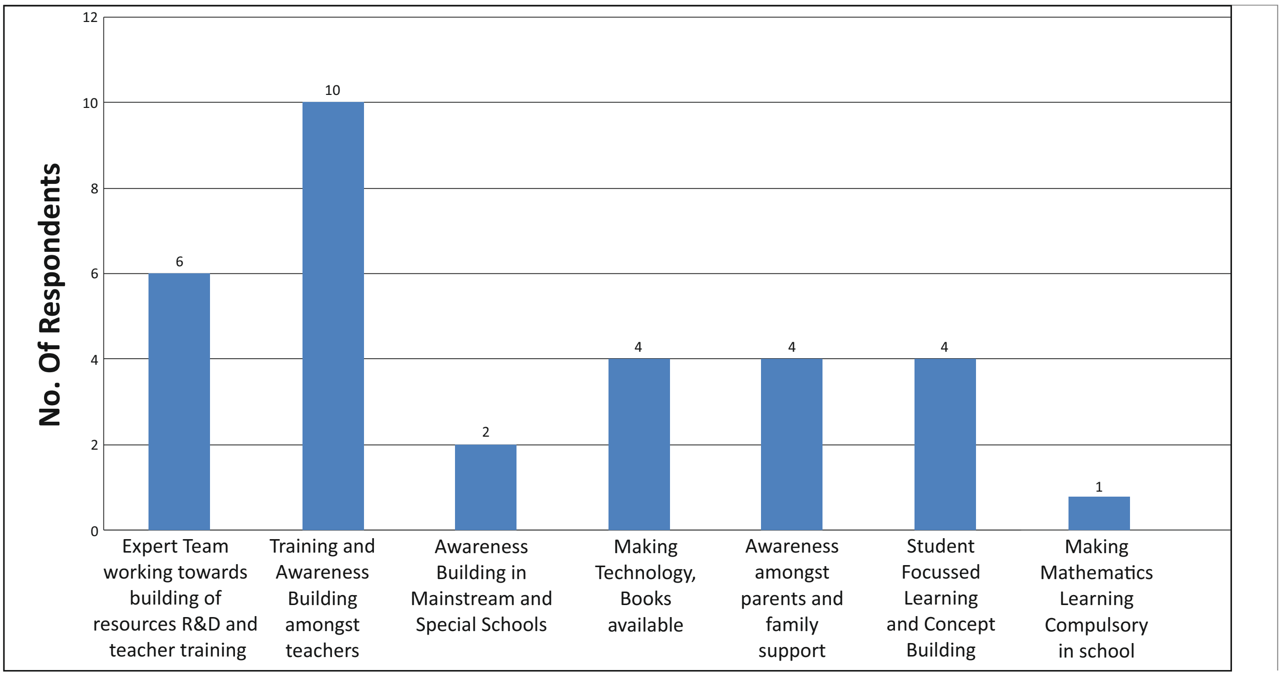
The data above corroborates the earlier two representations as well. What is extremely important to note is that the key concern with teaching-learning has not been reported as difficulty of the subject matter. Only a few aspects of the subject matter are found to be challenging, such as geometry. The key hurdle is in the attitude of schools and teachers- lack of encouragement and tendency to discourage students from studying maths and science or an assumption that blind students cannot study the same. This, coupled with lack of availability of material, tools and books and trained teachers, are the biggest challenges.

It becomes critical to address this gap on the field if any positive change in teaching-learning mathematics and science for blind and low-vision students is to be effected on the ground. Having stated the challenges faced, it is important to consider the views of the respondents on how these challenges can be overcome. The same is outlined in the following section.

Possible Ways of Overcoming Challenges faced in teaching-learning Mathematics and Science

Whist there are critical challenges faced in the teaching-learning process of mathematics and science currently due to lack of resources as also attitude of teachers, when asked for possible solutions to overcome the same, the respondents had the following key areas of intervention to recommend.

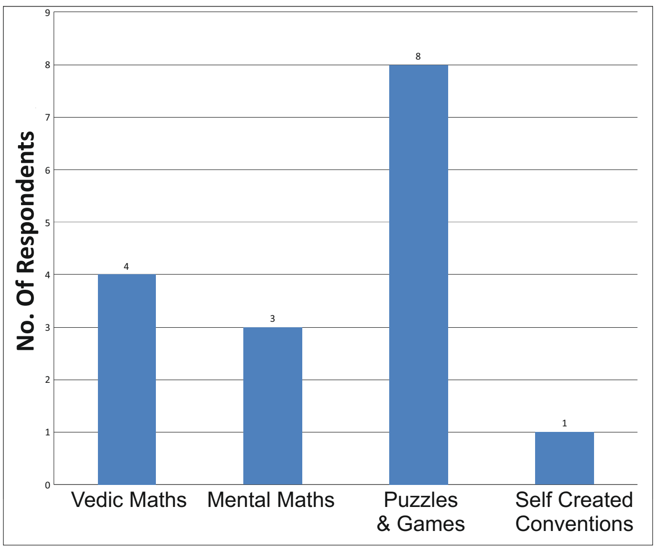
Figure 11: Ways of overcoming Challenges in mathematics and science teaching-learning



The above data clearly reflects that the key area of intervention found to be most important by students and teachers alike is in having a resource pool which can actively work towards awareness building and creation of resources for mathematics and science and making the same available. In addition to this there is also a need to emphasise on student focused learning and concept building and student motivation to ensure that learning happens well.

In addition to this key area of work identified, on exploring what are some of the innovative methods being used by users to overcome challenges the responses reflect the following:

Figure 12: Innovative Solutions used to overcome challenges



The responses in the area of innovative methods to overcome challenges tend to have shown a very strong weightage towards mental mathematics techniques. Also, puzzles and games can be used for both mathematics and science.

Having stated this the key area of intervention required on the field seems to be clearly outlined in the fields of Building a strong Resource Team working towards building resources, teacher training and awareness as also the use of mental maths, puzzles and games to see how mathematics and science learning can become easily accessible and available to all students with blindness and low vision.

The following chapter will highlight the key findings of secondary data to outline what is available currently in the field of assistive technology as also other tools and devices available and being used in India as also internationally to start bridging the gap of availability of resources and tools and lack of information related to the same being one of the biggest hurdles.

CHAPTER 3: ACCESSIBILITY OF MATHEMATICS AND SCIENCE FOR BLIND AND LOW-VISION STUDENTS

The earlier section has outlined the ground-level situations currently and the gap therein as regards Mathematics and Science Education in India. Having seen the gaps the next phase of the research tried to focus on secondary data-based research and testing to identify how these gaps can be bridged as also what are the resources available for the same.

This chapter will present the data collected through the secondary data research broadly under three sections:

Section I: International Research and Models
Section II: Assistive Technologies and Tools Available to address teaching-learning Needs
Section III: Catalogues of Available Products and Resources

Section I: International Research and Models

The International Research for available best practice and models has been restricted to online research. The attempt has been to get a sense of the International experience in teaching and learning of mathematics before the same can be explored in detail.

A cursory understanding of the science and mathematics learning the world over amongst the blind and low-vision is that the traditional apprehensions are prevalent internationally as well.

What is interesting is that even development of the Nemeth Code (The Braille Mathematic code) found to be such a fundamental way to access mathematics and science, was created by an Individual – Mr. Abraham Nemeth — to overcome the challenges faced at a personal level in studying higher level mathematics. Blind and low-vision students internationally are studying mathematics and science up to high school levels and also pursuing careers related to the sciences at the higher education level. However the methods employed for the teaching learning experience remain non-standard and primarily dependent on student-specific requirements and modifications possible.

What is a critical difference, however, is in the availability of university and organizational level support services and resources that enable this experimentation possible. Many of these services in the area of mathematics and science are still very new (primarily started over the last decade) and are still in the process of forming standards and quality material.

However the key lies in the legislative back bone, be it the American With Disabilities Act, 1991 or the Special Educational Needs & Disabilities Act, 2001 (UK) that lay out a strong foundation as also ensure effective implementation of the same where students with disabilities have access to admission to courses of their choice. Further, national level blindness organizations, be it the National Federation for the Blind (NFB) (www.nfb.org, www.blindscience.org), American Printing House for the Blind (APH) (www.aph.org) , American Federation for the Blind (AFB) (www.afb.org), etc in the U.S. or the Royal National Institute for the Blind (RNIB) (www.rnib.org.uk) have actively ventured out in creating resource materials wherever possible to make mathematics and science possible for the blind and

What is critical is that several special schools for the blind in the US have actively worked at strengthening mathematics and science learning rather than to giving concessions or discouraging the same. This is especially evident in the work undertaken at the Texas School for the Blind and the Visually Impaired through the work of Ms Susan Osterhaus (http://www.tsbvi.edu/math).

At the higher educational level, several universities through their Disability Support services have undertaken work on providing accessible resources and teaching-learning environment to blind and low-vision students. Especially through the last decade several interesting projects have been initiated in the U.S. to explore how Science, Technology, Engineering and Mathematics (STEM) subjects can be made more accessible for students with blindness and low vision. Many of these have been supported and funded through the U.S. Department of Education's office of Postsecondary Education and National Science Foundation. These have been located at various Universities across the U.S. and have been able to create some extremely interesting outputs. Some of the key projects are listed below:

Independent Laboratory Access for the Blind (ILAB) http://ilab.psu.edu/

ILAB was a *Research in Disabilities Education* project supported by the National Science Foundation. The project aimed at looking at inclusive and accessible teaching-learning in the STEM field. The ILAB project has lead to the establishment of Independence Science. The Project team for ILAB came from diverse educational institutes who at their respective campuses are also involved in similar work through their disability support services. These include Penn State University, Indiana School for the Blind and Visually Impaired, Truman State University, University of Wisconsin—Madison, and Hopewell Valley Central High School, Purdue University

Independence Science http://www.independencescience.com/

A product of the ILAB project, Independence Science is a company that is looking at creating inclusion in the field of STEM subjects for blind and low-vision students. It offers a range of products and services that can make the STEM classroom inclusive and equally enriching for a blind and low-vision student

MDW Educational Services, LLC, Science for the Blind: http://www.sciencefortheblind.com/

MDW Educational Services, LLC, Science for the Blind: http://www.scienceforttheblind.com/
A similar offshoot to the ILAB projects, MDW Educational Services also provides products and services to make STEM accessible to blind and low-vision students.

SciTrainU and SciTrain (http://www.catea.gatech.edu/scitrainU/ ;
http://www.washington.edu/doit/articles?502; http://www.catea.gatech.edu/scitrain/)

SciTrainU is a project funded through the Office of Post-secondary Education (US Department of Education) as a demonstration project hosted by the Georgia Institute of Technology and University of Georgia. The project provides online and offsite training resources for educators as also students for effective teaching-learning of STEM subjects at higher education level within college classrooms as also other learning environments . SciTrain is a similar programme for high school educators.

NASA and Other Space Programs for Blind and low vision students:
(http://www.nasa.gov/home/hqnews/2004/jul/HQ_04234_blind_students.html ;
http://www.spacecamp.com/specialprograms)

NASA, as also the US Space and Rocket centre in partnership with organizations and schools of the blind have started creating exposure camps and visits for blind and low-vision persons to get them oriented to space and astronomy concepts and career options. In addition NASA has also worked at creating accessible educational and learning content for blind and low-vision students.

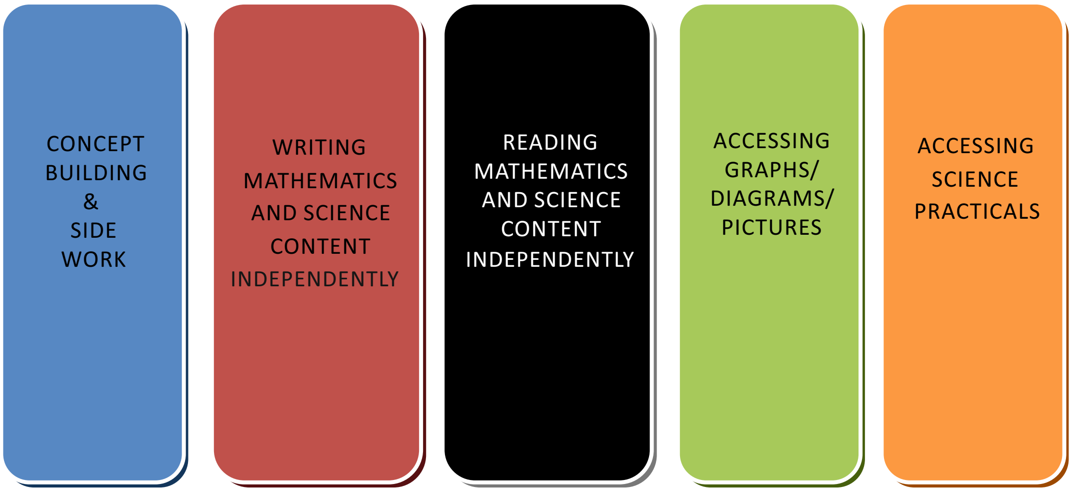
Hence, several projects have been initiated over the last decade or so that have started looking into accessible STEM subject teaching and learning.

However as *The American Printing House for the Blind, Mathematics Research Analysis report released in 2005-06 states* **"**It seems absurd that there is more information about the effectiveness of various consumer products than there is about the methods we use to teach children with visual impairments." And this seems to be the key gap. In the teaching-learning experience for blind students there are always two components—the tools and material to be used for teaching–learning and secondly the methods used by teachers and educators in teaching. Whilst a significant number of tools and their effectiveness evaluations has started being available in many of these international locations, the second part on teacher methods used to teach and some degree of standardized best practice in the area is still lacking. The projects mentioned above are starting points of some of the work in this area and one will have to monitor their growth to see how far they go.

In the mean time, given the gap in even the first part in India, it is considered useful to list out the available tools and assistive technologies in addressing the teaching-learning needs in the subject of mathematics and science. This is done in the following section:

Section II: Assistive Technologies and Tools Available to address teaching-learning Needs

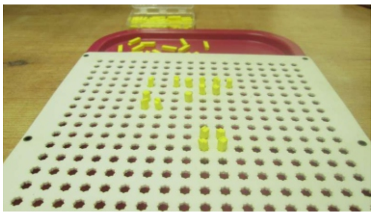
For the purpose of presenting tools and technologies available for teaching-learning again the 5 Pillar approach will be followed.



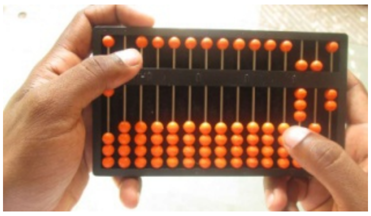
Concept Building and Side Work:

A whole range of tools and newer assistive technologies are available for the purpose of building concepts and understanding the spatial nature of mathematics at the early levels of learning.

Non-Electronic/Technology Options:

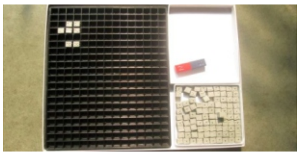


- Taylor Frame: Used to write mathematics with use of tactile types for various functions of mathematics. Allows for spatial orientation whilst writing like sighted writing.
- Abacus: Tactile calculation and writing device.

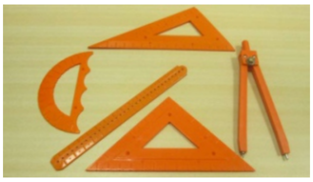


- Perkins Brailler/Braille Slate and Stylus: Mechanical brailler that allows you to physically write mathematics in Nemeth Code on the same side. If this is not available the standard Braille slate and stylus can also be used.

- Cubarithm: Tactile slate to write mathematics with Braille cubes. Allows for spatial orientation whilst writing. Similar to the Taylor Frame, but the students can use Nemeth Code notations instead of learning the Taylor Frame types code.



- Braille Geometry Kits with spur wheel drawing or with Sewell line drawing kits: Used for doing geometry constructions. The spur wheel paper permits reverse drawings, whereas the Sewell line drawing kit permits same side construction.



Electronic/Technology Options:

- VP Arithmetic, VP Algebra: Software program that permits writing of mathematics spatially, accessible with audio.
- Marvel Maths /Math Flash: Audio supported mental maths exercise programs.
- Calculators: A range of talking calculators is available. These could be either inbuilt in MS Word, Apple calculators used in conjunction with screen reading programs. Ipad talking calculator applications, hardware talking calculators available for basic functions or Scientific talking calculators available with Orbit research and the new TI-84 – talking audio graphing calculator available with the same.

- Sonic Labeler/Pen friend with graph paper: An innovative way to create an electronic slate could also be a tactile graph paper which creates boxes, within which a pen friend (audio labeler) can be used to insert labels and write mathematics in each graph cell through instant recording which can be read aloud as also re-written.

- Excel with screen reader/magnifier: A simple Excel spread sheet with a screen reading and magnification program could also be used to achieve writing and understanding of mathematics. However, this is found useful at a slightly advanced stage once the spatial orientation of tens, hundred, etc has been gained through a tactile spatial board.

Key Observations:

- The key gap that continues to exist at the concept building stage is the joint experience between a blind student writing independently on Taylor Frame/Perkins Brailler/Cubarithm and the sighted teacher being able to read it simultaneously without depending on the student. That gap is bridged through software programmes such as VP Arithmetic/Algebra or Excel.
- However, relying exclusively on software programmes would pose the problem of its lack of tactile field to build strong understanding, at least in the initial phase of learning.
- Hence what would be desirable is to ensure a degree of tactile spatial learning at the early stage depending on the learner's capacity and to transition to the electronic programs at the later stage to bring VI-Sighted common access to mathematical workings.
- An additional challenge while using tools like the Taylor Frame, Abacus or the Cubarithm is that they do not permit work to be saved. Hence work once done cannot be stored for later practice or revision.
- In addition, research can also be undertaken to create a mechanical/tactile device at the learning stage itself which supplements the spatial slate with tactile and a visual and/or audio display making it a multi access device for both the blind and the sighted. And a capacity to store the work done on such a device would be an additional factor that would make teaching learning far more effective.

Writing Mathematics and Science Content Independently

When it comes to writing mathematics independently, depending on the student, both Braille and non Braille options are available.

Braille Options:

- Mechanical Brailler: Allows for material to be physically typed in Nemeth Code and stored as paper.
- Electronic Brailler: Permits material to be physically typed in using Nemeth Code, either stored electronically and read back on a refreshable Braille system or printed on paper through a Braille printer.
- Electronic Brailler + Nemetex: Nemetex as software permits electronic Braille to be converted into sighted writing. Making it possible for the work undertaken in Braille to be made available to a sighted teacher.

Audio Options:

- Mathematics is sometimes learn/taught completely orally with either reliance on a sighted writer or recording of mathematics on an audio recorder. Whilst this is not efficient in the

Electronic Options:

Screen Readers/Magnifiers: The challenge with computer access for writing mathematics has been because of two factors. Firstly, within the sighted world as well, typing mathematics effectively on the computer because of its spatial nature has not been as straightforward as language typing. There has always been the need to either rely on Mathematics/Science equation editors or rely on mathematical language such as TeX, LaTex etc.

Taking that challenge forward in the world of the blind comes with access of the mathematics equation editors or mathematical language programmes to screen readers and magnifiers. Or even the readability of basic mathematical symbols in a Word programme to a screen reader and magnifier. As also the ease of access of keyboard commands for inserting mathematical symbols.

Some of the solutions that exist are as follows:

- Word and Excel with Screen Readers: Here the mathematical equation editors inbuilt in the word processors are often inaccessible. One could type in maths in the linear mode as well. However here, the screen readers do not read back all mathematics symbols as yet. And the additional challenge is that written work may not have the same spatial orientation that a sighted teacher would prefer.
- Screen Reader + Latex + Math Type + Math ML: The additional option is to use Latex with a screen reader to type content in a word processor. In order to do so the student will have to learn the Latex code. Once Latex is keyed in, Math Type software with a keyboard command can convert it into spatial mathematics format, which in turn can be published as a Math ML book which is accessible to a screen reader. The VI student will not have screen reader access to the sighted published work which is the in-between stage to show the work to the sighted teacher. Should any changes need to be made the student can, with a keyboard command, revert to Latex to make the necessary changes.
- Specialized Equation Editors: (e.g. Infty Editor + Chatty Infty; LEAN Maths): These editors, having been designed especially for blind users, have aimed at trying to develop programs with easy entry key board commands or use of Latex with the converted sighted format also accessible through audio.

Key Observations

- The key to independent writing of mathematics is the access to the written material jointly to the blind and the sighted as also easy access and storage of the same.
- Whilst the electronic brailler with Nemetex permits joint access, the cost of electronic braillers in India remains a huge concern for access.

- For the computer options, one key challenge that remains is the ease of typing — the learning curve to learn either Latex or any other typing commands for quick mathematics typing. The other key challenge is in the read-back standardization of written work (with meaning, e.g Two raised to N v/s two to the power of N) and the ease of the same when work is underway. And thirdly, in access of the technology being used for students.
- In order to make computer mathematics accessible to all an ideal situation would be to have a screen reader with a standard word processor to have an intuitive simple typing system for effective and quick keyboard typing of mathematics and the ability to at least read back all mathematical symbols. The read-back capacity to more meaningful reading can then be added on incrementally. The need for the mainstream processors to be able to do effective typing and read back with a standardized screen reader without any additional math software is especially critical in countries like India, where the basic technology is yet to reach all. Hence it would be extremely desirable to build up the inbuilt capacity of the basic technology for mathematics access rather than depend on specialized programs alone.

Reading Mathematics and Science Content Independently

In order to read mathematics and science content independently, one needs books in accessible formats. What constitutes an accessible book for mathematics and science differs marginally from other language and theory books. This is on account of the concerns illustrated in the above section — that neither are all mathematics symbols read out accurately by a screen reader, nor is the meaningful addition to mathematics reading effectively done by all screen readers. Hence, for reading books the following options exist.

Braille Options

- Hard Copy or Soft Copy Braille: One can access Nemeth content either as hard copy books or soft copy on refreshable Braille displays.

Audio Options:

- Human recorder audio is an option still exercised by several users on the ground.

Electronic Options:

- An electronic text having mathematical content is only accessible provided the same is available either as a Math ML book, Math DAISY book and other such specialized formats.
- The same can be read through use of Math Player or DAISY readers with special math capacity such as the Dolphin Easy Reader or ReadHear.
- One can also use softwares such as Infty Reader to scan and convert hard copy books into accessible soft copies.

Key Observations

- Self-creation of accessible mathematics and science content by the blind user is not as effective as self-creating other theory content, as the scanning and OCR systems for mathematics are still not high on efficiency.
- Creating electronic accessible content in mathematics often involved needing the source code in Latex. If the same is not available it involves physically typing the mathematical content using a mathematical editor such as Math Type or others.
- There is always reliance on an additional plug-in such as Math Player or a DAISY reader with math support to read the accessible copy, as a standardized screen reader would not be able to do the same.
- In India no concentrated effort to create accessible math content in electronic format is underway and the Braille hard copy books are available only till 10th std. Largely, human recorder audio/DAISY books are being used for any higher level mathematics. Hence, lack of content remains a huge gap.

Accessing Graphs/Diagrams/Pictures

With accessing graphs, diagrams and pictures there are multiple factors at play. Firstly, as illustrated in the earlier section, whether the visual is a 2D representation of a 2D line drawing as against a 2D representation of a 3D image makes a key factor on what type of accessibility solution will work. Further, accessibility of graphics is both from the perspective of creating graphics as also accessing graphics that are already published. The following options exist :

Non-Electronic/Technology Options:

- Spur Wheel and paper: Used to draw reverse images. Can be used to construct images by blind and low-vision users as also used to manually create images to study.
- Sewell Line Drawing Kit: Used to draw same side. Can be used to construct images by blind and low-vision users, as also used to manually create images to study.

- 3D Models and other tactile diagrams: These constitute a range of real-life objects of 3D models of objects available locally or 2D diagrams made using variety of materials — such as thread, sticks, glitter, thick glue, etc.
  Can be used to both construct independently as well as create, and can be sourced locally or created manually through various readily available items such as strings, thick glitter, etc. In addition latest 3D printing technologies can also be used to make custom-required models for learning.

- Other Aids: Wiki sticks (flexible wax sticks which can be stuck on any board), String Along (Thread and thermoform board), Geo Board (Thread and wooden board), Magnetic pegs and metal board (Shapes with magnets). Taylor Frame with Rubber Bands: All of these can be used for instant construction and learning.

Wiki Stick

Metal Board with Magnetic Pegs

Geo Board

Electronic/Technology Options:

- Graphing Softwares: Audio and verbal description based graphing softwares such as Audio Graphing Calculator(AGC) and Math Trax make electronic graph construction and access feasible.
- PIAF Tactile Diagrams: The PIAF (Picture in a Flash) diagram machine can create accessible 2D images with different textures and shapes. The same cannot be used for constructing images by blind and low-vision users, but used to publish accessible images.

- Talking Tactile Tablet : This is another hardware and software device that is used to publish accessible images that combines audio with the images.
- Sonic Labeler/Pen Friend labeling device: This is an audio labeling device which can be used effectively for published tactile diagrams to add labeling beyond Braille labels.
- TI-84 Talking Graphing Calculator: The latest talking scientific calculator which comes with an audio graphing add-on.
- SVG Graphics: Special format that can make graphics accessible.

Key Observations

- Internationally there is significant research being undertaken to create standards for effective tactile diagrams.
- For effective use it is essential that a mix of 3D models and 2D diagrams are used, and also supplemented with good explanation and orientation.

Accessing Science Practicals and Lab Work

This is an increasingly evolving area. Research on creating both tools and technologies to make the labs accessible is fairly recent and hence resources here are more evolving. From the ones that already exist the following are some of the ideas.

- **Talking Lab Quest and Logger Pro (With Sci Voice Access Software) :** An accessible solution of the Lab Quest and Logger Pro program, this enables blind or low-vision students to access a range of science experiments to collect data and have the same read out to them through audio. The accessibility is achieved through the Sci Voice Access Software add on.
- **Automatic Stir Station:** This enables for safe use of experiments involving stirring etc.
- **Drop Counter:** This enables counting of drops and conducting accurate experiments.
- **In-house Tactile markers:** Several locally available tactile markers such as raised dots with glue, threads, etc used to mark lab equipment to make the same accessible. Also simply, use of touch to gain orientation and familiarity facilitates independent use of the equipment at a later stage
- **Talking BP machines, Talking Glucometer, Talking Physiotherapy machines:** Similar talking devices are available to facilitate independent practical work in the fields of physiotherapy or related fields.
- **Light sensors/probe:** Useful in detecting light and hence useful in doing experiments related to light, refraction and others.

Key Observations

- Work and methods in this area is evolving.
- Resources and teaching methodologies are being evolved through some key projects such as Independence Science, SciTrain and SciTrainU.

Thus a range of tools and equipments are available to facilitate teaching-learning experience of mathematics and science. As the key observations in each section above mention, there are certain gap areas that continue to exist on which research is underway.

In order to facilitate the choice of the right tools and technologies, it is important to identify the level of teaching as also the learner's capacity and comfort with the tool of choice. No single tool will work for all and it is the right selection based on user needs and skills that will make teaching-learning a fun and an effective experience. The section above has tried to list to the best of our capacities available key tools and technologies in the area which could be a good starting point for the selection.

Further, we have undertaken user-level testing of some of the main softwares mentioned in the above section in order to offer Indian ground level feedback which might prove crucial in understanding these softwares in greater detail beyond what is mentioned above. The same are attached in ANNEXURE … The user reports reflect the views of the testers as recruited in this research and do not claim to be absolute in their judgement. We would request anyone using these reports to further explore its applicability for your specific situation and need.

Section III: Catalogues of Available Products and Resources

Throughout this research process the research team found that whilst resources were limited on the ground, lack of information about even the limited resources was making things even more difficult. Further when an effort was made to start collating resources available in India locating the exact nature and extent of the same has been difficult. However what has been found to be important is to make a beginning and start the process of compiling what could be identified and we hope that this could become an evolving catalogue where over the years additions could be made.

The attempt has been to locate sources for all the above mentioned tools and resources to begin with and key resource organizations and groups that can become valuable source of information for a student, teacher or caregiver to learn more. In addition we have also tried to list out the library resources through which book content available for maths and science can be accessed. The focus of the catalogue is India and International sources for products have been added where no corresponding Indian Counterpart could be found.

CATALOGUE 1: TEACHING LEARNING TOOLS AND TECHNOLOGIES

Area of Use	Name of Tool/Instrument/Technology	Use	Manufacturer/ Supplier Name	Supplier Link
Concept Building and Side Work				
	Taylor Frame and Type Sets for the frame (Algebra, arithmetic)	Used to Write Spatial Mathematics	National Institute of Visually Handicapped (NIVH),Worth Trust, Advance Engineering Works, National Association for the Blind, Saksham	www.nivh.gov.in; www.worthtrust.org.in; www.advancebraille.com; www.nabindia.org; www.saksham.org
	Abacus : Plastic - Pocket Size	Mathematics Calculations	National Institute of Visually Handicapped (NIVH), Worth Trust, National Association for the Blind, Saksham	www.nivh.gov.in; www.worthtrust.org.in; www.nabindia.orgm; www.saksham.org
	Cubarithm	Used to Write Spatial Mathematics in Braille	RNIB, Saksham,	www.rnib.co.uk ; www.saksham.org;
	The Perkins Brailler - Standard Model	Writing in Braille (Nemeth Code)	Worth Trust	www.worthtrust.org.in
	The Next Generation - Perkins Brailler	Writing in Braille (Nemeth Code)	Worth Trust	www.worthtrust.org.in

	Braille Slate and Stylus	Writing in Braille (Nemeth Code)	National Institute of Visually Handicapped (NIVH), Worth Trust, Advance Engineering Works, National Association for the Blind, Saksham	www.nivh.gov.in; www.worthtrust.org.in; www.advancebraille.com; www.nabindia.org; www.saksham.org
	Eraser made out of Plastic for use with Perkins Brailler/Braille Slate		Worth Trust	www.worthtrust.org.in
	Universal Braille Kit (Braille Slate, Stylus, English & Hindi / Tamil Trainer Plate, Geometry Set, White Cane , Word Block (5), Cube, Tracer Wheel, Paper(20), Taylor's Frame, Abacus, Type sets, Manual, Back pack)	Writing in Braille	Worth Trust	www.worthtrust.org.in
	Mini Universal Braille Kit (Braille Slate, Stylus, Abacus, Geometry Set, Braille Cube, Word Block (5), Tracer Wheel, Paper(20), Mini Taylor's Frame, Vikas Composer, Manual, Bag)	Writing in Braille	Worth Trust	www.worthtrust.org.in

	Braille Mathematics Code for India Book with tactile images of signs	Learning Braille Mathematics Code for India	NAB India	www.nabindia.org
	Tables of Square roots, logarithm of numbers, of trigonometric functions	Learning logarithm	American Printing House for the Blind	www.aph.org
	The Nemeth Braille Code for Mathematics and Science Notations 1972 Revision	Exhaustive list of Nemeth's notations	American Printing House for the Blind	www.aph.org
	Unified English Braille Guidelines for Technical Material	Work in Progress related to the Unified English Braille Code	International Council of English Braille	www.iceb.org; www.iceb.org/Guidelines_for _Technical _Material_2008-10.pdf ; http://www.iceb.org/Rules%20of%20Unified%20English%20Braille%202013.pdf
	An Introduction of Braille Mathematics Book (Nemeth Code)	Learning Nemeth Code	NA	NA
	Geometry Set - Standard and Large	Use for Geometry Constructions	National Institute of Visually Handicapped (NIVH), Worth Trust, Advance Engineering Works, National Association for the Blind,	www.nivh.gov.in; www.worthtrust.org.in; www.advancebraille.com; www.nab.gov.in
	Spur Wheel and Paper with Rubber Mat	Used for Drawing reverse	Worth Trust	www.worthtrust.org.in

	Plastic Sewell Line Paper with Rubber Mat	Used for Drawing Same Side	Sewell Line Plastic Paper available under name of Parchment paper at All India Plastics (At the store locally known as plastic paper for the blind); Rubber Mat available at NAB India, Worli, Mumbai	www.allindiaplastics.com / www.nabindia.org
	VP Arithmetic, VP Algebra	Writing Mathematics Spatially on the Computer with Audio Feedback	Henter Maths	www.hentermath.com
	Marvel Maths	Mental Maths with Audio Feedback	MarvelSoft Enterprises	www.braillebookstore.com
	Math Flash	Mental Maths with Audio Feedback	American Printing House	www.aph.org
	Basic Talking Calculators	Mathematics Calculations	Saksham	www.saksham.org
	Scientific Talking Calculators	Advanced Mathematics Calculations	Orbit Research	www.orbitresearch.com
	Talking Scientific Audio Graphing Calculator TI-84	Advanced Mathematics Calculations with additional audio graphing display feature	Orbit Research	www.orbitresearch.com

	Tactile Graph Paper	For Graphs or spatial maths	RNIB, Saksham	www.rnib.co.uk ; www.saksham.org
	Talking Audio Labeler – Sonic Labeler Pen friend	Labelling diagrams or Spatial maths in conjunction with tactile graph paper	RNIB, Saksham, Go Discover	www.rnib.co.uk ; www.saksham.org; www.godiscover.co
	Screen Readers and Magnifiers : e.g JAWS, NVDA, Dolphin Supernova	For accessing Word processing and Excel	Freedom Scientific, NVDA, Dolphin	www.freedomscientific.com ; www.nvaccess.org; www.yourdolphin.com
Writing Mathematics and Science Content Independently				
	Electronic Braille Note Machines (E.g. Braille Note Taker, APEX, Pac Mate)	Writing and reading Braille Electronically (Nemeth Code)	HumanWare; Freedom Scientific	www.humanware.com ; www.freedomscientific.com
	Refreshable Braille Displays (E.g Focus 40, EasyLink, ALVA USB640)	Writing and reading Braille Electronically on the computer (Nemeth Code)	Freedom Scientific; Optalec	www.freedomscientific.com; www.optelec.com
	Nemetex	Conversion of Electronic Braille into Sighted Print	Accessisoft	www.accessisoft.com

Area of Use	Name of Tool/Instrument/ Technology	Use	Manufacturer/ Supplier Name	Supplier Link
	Math Type	Conversion of Latex into Sighted Print with save as Math ML option	Design Science	www.dessci.com
	Infty Editor + Chatty Infty	Specialized Math Editor for writing mathematics	Infty Project	www.inftyproject.org
	LEAN Maths	Specialized Math Editor for writing mathematics	LEAN Math	Not Available yet (2013 Beta release)
	Math DAISY	Creation of Math DAISY Books	Design Science	www.dessci.com
Reading Mathematics and Science Content Independently				
	Math Player	Mathematics Content Reader	Design Science	www.dessci.com
	Dolphin Easy Reader	DAISY Reader with math capability	Dolphin	www.yourdolphin.com

	ReadHear	DAISY Reader with math capability	gh Accessibility	www.gh-accessibility.com
	Infty Reader	OCR with Math capability	Infty Project	www.inftyproject.org
Graphs/ Diagrams/ Pictures				
	Spur Wheel and Paper with Rubber Mat	Used for Drawing reverse	Worth Trust	www.worthtrust.org.in
	Plastic Sewell Line Paper with Rubber Mat	Used for Drawing Same Side	Sewell Line Plastic Paper available under name of Parchment paper at All India Plastics (At the store locally known as plastic paper for the blind); Rubber Mat available at NAB India, Worli, Mumbai	www.allindiaplastics.com /www.nabindia.org
	Wiki Sticks	Used for any shape and drawing activity	RNIB, Saksham, Wikki Stix	www.rnib.co.uk ; www.saksham.org; www.wikkistix.com
	String Along (Thread and Thermoform	Useful for drawing and shapes	RNIB, SakshamSide	www.rnib.co.uk ; www.saksham.org
	Geo Board (Thread and wooden board)	Useful for drawing and shapes	Local Toy Stores	NA
	Metal Board with Magnetic Shapes	Useful in learning shapes	RNIB, Saksham	www.rnib.co.uk ; www.saksham.org

Area of Use	Name of Tool/Instrument/ Technology	Use	Manufacturer/ Supplier Name	Supplier Link
	Audio Graphing Calculator Software	Software useful in constructing and accessing computer graphs	View Plus	www.viewplus.com
	Math Trax	Software useful in constructing and accessing computer graphs Swith verbal description	NASA	prime.jsc.nasa.gov/ mathtrax
	PIAF Tactile Diagram Machine	Creates Tactile Diagrams	Quantum	www.quantumrlv.com.au
	Talking Tactile Tablet	Useful in publishing and accessing images with audio feedback	Touch Graphics	touchgraphics.com
	Tactile View	Software useful to make raised graphics on Braille	Tactile View	www.tactileview.com
	Talking Audio Labeler – Sonic Labeler/Pen Friend	Labelling diagrams or Spatial maths in conjunction with tactile graph paper	RNIB, Saksham	www.rnib.co.uk ; www.saksham.org
	Talking Scientific Audio Graphing Calculator - TI- 84	Advanced Mathematics Calculations with additional audio graphing display	Orbit Research	www.orbitresearch.com

	3-D Models	Useful in understanding figures and objects	Can be sourced from a variety of local stores. One such is Navnirmiti, Mumbai, or international sources	www.navnirmiti.org; http://www.didax.com/shop/productdetails.cfm/ItemNo/5-361.cfm
	Biology models and other maths and science related educational aids	Useful in studying mathematics and science	INDOSAW	www.indosaw.com
	Talking LabQuest - Data Collection Tool with Sci Voice Access Software	Accessible Data collection for Performing science practicals	Independence Science	www.independencescience.com
Science Practicals and Lab Work				
	Talking Logger Pro - Data Analysis Software with Sci Voice Access Software	Accessible Data analysis of practicals	Independence Science	www.independencescience.com
	Automatic Stir Station	Useful in performing science practicals	Independence Science	www.independencescience.com
	Light sensor/probe	Useful in light/ refraction related experiments	RNIB (under the name Colorino)	www.rnib.co.uk

Area of Use	Name of Tool/Instrument/ Technology	Use	Manufacturer/ Supplier Name	Supplier Link
	Drop Counter	Useful in performing science practicals	Independence Science	www.independencescience.com
	Talking BP Machine	Useful in Physiology related practicals	Saksham	www.saksham.org
	Talking Glucometer	Useful in Physiology related practicals	BioSense Medical devices	http://biosensemd.com/
	Talking IFT Machine	Useful in Physiotherapy Practicals	Johari Digital Unique Medical Appliances	www.joharidigital.com ; www.uniquemedicals.com
	Talking Ultrasound Machine	Useful in Physiotherapy Practicals	Johari Digital	www.joharidigital.com

** RNIB products are available from Saksham at the email id mentioned above*
**For International manufacturers with available contact details, we have tried to restrict details for the manufacturer.*
Local dealer information for the same is available on the manufacturer's websites as the same could be dynamic.

CATALOGUE 2: LIST OF USEFUL ONLINE RESOURCES

Maths Teaching -Learning Resources
www.tsbvi.edu/math/
www.access2science.com
Science Teaching Learning Resources
www.independencescience.com
http://ilab.psu.edu/
www.sciencefortheblind.com/
www.catea.gatech.edu/scitrainU/
www.washington.edu/doit/articles?502
www.catea.gatech.edu/scitrain/
www.nasa.gov/home/hqnews/2004/jul/HQ_04234_blind_students.html
www.blindscience.org/
http://www.icevi.org/publications/icevi_wc2006/ 02%20%20access_to_curricular_and_extra_curricular_areas/Papers/ea_046_yoshiko%20toriyama.pdf; http://www.tsukuba.ac.jp/english/organization/lab_schools/gokokuji.html
Tools/Books/Learning Aid Resources
http://163.238.35.147/CalculusForTheBlind/index.html
http://lunarscience.nasa.gov/tactile/
http://hubblesite.org/newscenter/archive/releases/2002/28/video/a/
http://prime.jsc.nasa.gov/earthplus/software.htm
http://aim.cast.org/
www.abledata.com/abledata.cfm?pageid=19327&top=13205&trail=22,13134
Resources for making Tactile Diagrams
http://www.piaf-tactile.com/tactile-graphics-resources.html
http://www.artbeyondsight.org/handbook/acs-tactileguidelines.shtml
http://www.perkins.org/resources/scout/education/geography/creating-tactile-graphics.html
http://www.purdue.edu/odos/drc/tactilediagrammanual.php
http://www.tsbvi.edu/component/content/article/107-graphics/3189-tactile-graphics-resources
http://brailleauthority.org/tg/web-manual/
http://www.smarterbalanced.org/wordpress/wpcontent/uploads/2012/05/TaskItemSpecifications/Guidelines/AccessibilityandAccommodations/TactileAccessibilityGuidelines.pdf
http://www.aph.org/manuals/7-30006-00.pdf
https://www.bookshare.org/_/aboutUs/2010/03/diagram
E Groups
Blind Math : http://www.nfbnet.org/mailman/listinfo/blindmath_nfbnet.org
NFB Computer Science: http://www.nfbnet.org/mailman/listinfo/nfbcs_nfbnet.org
NFB Science: http://www.nfbnet.org/mailman/listinfo/nfb-science_nfbnet.org
NFB Maths Gems (Excellent summarized resource of Blind math group over the years):

CATALOGUE 3: ONLINE LIBRARIES WITH MATHEMATICS AND SCIENCE CONTENT

www.oblindia.org
https://www.bookshare.org/?c=en_IN

CHAPTER 4: CONCLUSION AND THE WAY FORWARD

The Maths and Science Access project undertaken by the XRCVC, Mumbai, India has been able to create a holistic understanding of the ground realities of mathematics and science learning in India currently. The research undertaken had the dual purpose of being able to understand ground realities and, based on the same, conceptualize a project to increase the access of mathematics and science learning amongst blind and low-vision users. What the research has not aimed to cover is teaching methods to be employed by educators. The project hopes that the first step has to be to identify tools and resources and that through its next stage of implantation, through process documentation, it would be able to identify teacher-student strategies for effective learning.

The key conclusions of the current level of research exercise can be said to be the following:

1. Currently the percentage of students undertaking mathematics and science education in India even up to the 10^{th} grade is negligible.
2. Despite lack of resources and facilities over the years, students with a keen interest and aptitude in science and mathematics have pursued these subjects beyond primary education.
3. The challenge lies in taking mathematics and science education amongst the blind and low-vision students not only to the select few but the majority.
4. The key obstacle in lack of access has been the lack of information and perceived myths about the blind and low-vision student's inability to pursue mathematics and science amongst teachers, school and students themselves and their families.
5. There is also a very acute shortage of teaching-learning content and resources available in the area of mathematics and science in India and most students have had to rely on sighted assistance or self-made strategies and tools. Along with this there has also been lack of awareness and skill amongst teachers including special educators on the knowhow and use of tools and technologies that can be employed for an effective teaching-learning experience. This has further compounded the perceived difficulty and myths.
6. Today, internationally several tools and technologies exist that facilitate mathematics and science learning for blind and low-vision users. However, these tools cannot eliminate the use of a teacher for conceptual clarity just in the same way as a book cannot replace a teacher for a sighted student. The need for good conceptual clarity is the key for a blind student to be able to rely on mental mathematics or other quick ways of handling mathematics and science content at higher levels of education.
7. Even internationally whilst tools and resources are more readily available compared to India, work on documentation on best teaching practices for mathematics and science has began only over the last decade. Interest and research on the blind and low vision pursuing Science, Technology, Engineering and Mathematics (STEM) has increased over the last decade.

Having stated the above, there is a crying need to conceptualize and initiate an active project for mathematics and science access in India. Whilst a complete project cannot be conceptualized, what we seek below are the key areas in which intervention is critically required and where the XRCVC would like to make a beginning.

- Availability of Teaching-Learning Aids and Content
- Awareness amongst teachers, schools, special educators, students and families
- Effective resource sharing and networking between individuals and organizations to be able to achieve maximum with the limited resources at hand, especially in the beginning.
- Training of teachers and educators in the field of mathematics and science learning for blind and low-vision users. Availability of teaching and support services for blind and low-vision users

Whist most of this will evolve with time, the XRCVC aims to launch a pilot project that can set a replicable model for the same to be expanded at a future date.

The pilot project would aim to focus on the following

1. **Math Science Access E Group**: The International experience has been very strong on demonstrating the value of sharing of ideas and resources between users, resource persons and organizations via a common online platform in being able to bridge the information gap as also being able to provide innovative solutions on the ground in face of scarce resources. Given the nascent stage at which the field of maths and science access is in India, one of the first efforts of the pilot project would be to set up an online e-group. The group is not intended to duplicate the rich resources already available on International e-groups; however it will be able to focus sharing of ideas and resources which are specific to the Indian context and requirements.
2. **Availability of Teaching-Learning Aids (TLA) :** The XRCVC would like to begin work on creating a networked library resource amongst different organizations in India that house teaching-learning aids for mathematics and science, and to fill in the missing gaps of tools currently not available in India. The XRCVC, similar to its assistive technology section, would like to ensure that it becomes a resource house of information and aids and equipments related to mathematics and science learning and hence be able to effectively guide end users based on specific requirements.
3. **Content Creation and TLA manufacturing:** The XRCVC would like to begin exploring the in-house or outsourced production of books as also TLA amongst a network of organizations, to ensure that books to begin with are available in multiple accessible formats for up to 10th grade across India for mathematics and science. Further, some of the valuable TLAs available internationally are not easily available at affordable costs in India and the XRCVC would like to begin exploring the possibility of how the same can be bridged.

4. **Learning services to Students and Training of trainer services to educators:** The XRCVC, to begin with, would like to start working with an in-house special educator who would be able to offer quality learning services to end users in teaching-learning of mathematics. The same effort over the years would like to upscale itself in providing training for trainers in the field to create the much needed human resource base.
5. **Awareness:** This has been one of the most critical areas of intervention. However, as mentioned earlier, lack of resources have often further strengthened the fears and myths. The XRCVC would therefore like to begin its active awareness campaign with schools, educators, parents and students once it has set up a basic level of teaching learning resources and learning services in the field. This would ensure that the awareness campaign does not backfire but would trigger incremental growth over the years.

The XRCVC, over the coming calendar year, will begin and initiate specific work under this pilot project and hopes to make a strong beginning to create access in the field of mathematics and science for students in India.

The XRCVC strongly believes that resource sharing and networking are one of the most effective strategies to create successful programs on the ground that have lasting impact. The XRCVC would like to request anyone accessing this research report, to please feel free to contact us should they like to contribute to the XRCVC's project in any way – through time, ideas or in any other manner. Updates on the Maths and Science Project at the XRCVC will be posted on its website — www.xrcvc.org.

Please feel free to access the same for information and resources relevant and useful to your needs. If you have any query related to the report or the project or any of XRCVC's other initiatives, please feel free to contact us.

ANNEXURE A - QUESTIONNAIRE – INDIVIDUALS AND ORGANISATIONS

Maths and Science Project

Many of us over the years have recognized a critical gap area in education initiatives of the visually impaired in India. A key area of concern has been that in the area of mathematics and science education and its access across the country for visually impaired students.

Saksham and XRCVC in partnership have taken up a Math and Science Access project through which we hope to make a beginning in this area of work. One of our first mandates under this project is to research and identify the most appropriate teaching-learning process and content to impart Mathematics and Science education to varied groups of visually impaired students (totally blind, low vision, children and adult learners)

In order to achieve this we are starting off a research project to collect the ground level data.
Since this is such a new area for all of us, starting off with researching at places where we know work is currently happening or to start talking to individuals who have studied or are interested would be most useful and we would like to garner the strength of everyone's information to be put to best use of the project.

We will be grateful if you could spare your precious time to fill up the questionnaire.

Thank you

The XRCVC Team.

(Instructions to fill up the form - Please write your answer below the questions. Give blank lines if necessary. Please send over the filled form to arshia@xrcvc.org within three working days of receiving the mail)

Questionnaire:

Please Note:

1. Please type out the answers after the end of the questions. Also write N.A.(not applicable) in front of any question not applicable to you.

E.g.: If you are not a post graduate then type out N.A. in front of that question
Demographics:

Q1. Name:

Q2: Gender: Male/female (keep your choice and delete the other word)

Q3: Age:

Q4: Landline Number and Mobile Number:

Q5: E-mail ID

Q6: Are you studying currently?   Yes/ no (keep your choice and delete the other word)

Q7. If you are studying, where are you studying?

Q8. If you are studying what level are you studying at?

Class 6-8/ class9-10/class 11-12/ graduation/post graduation /adult learner/ learner for competitive exams (keep your choice and delete the other word)

Q9. Are you working? Yes/ no (keep your choice and delete the other word)

Q10. If you are working, where are you working?

Q11. In your organization what are you working as?

Head of Special School for (totally blind/low vision)/Head Integrated school for the (totally blind/low vision)/Teacher at a special school/Teacher at an integrated school/Teacher at a college/Special Educator/Parent of (totally blind/low vision) /Head of NGO working for the (totally blind/low vision) /Staff of NGO working for the (totally blind/low vision) /
Other ______________

(Keep your choice and delete the others)

Section I: General Profile

Q1. Are you a person with visual impairment?   Yes/ no (keep your choice and delete the other word)

Q2 If you are an individual with vision impairment then are you totally blind/low vision (keep your choice and delete the other word)

Q3. If you are totally blind then are you born blind / late blind? (keep your choice and delete the other word

Q4. If you are totally blind/low vision, name the school that you are studying in or have studied in earlier.

Q5. If you are totally blind/low vision and if you have or are doing graduation, name the college from which you did your graduation.

Q6. If you are totally blind/low vision and if you have done post graduation, name the college from which you did your post graduation.

Q7. If you are head or teacher of Institution/school give the number of totally blind and low vision students. Also please give percentage wise blindness profile amongst students.

Q8. If you are totally blind/low vision, till what level have you studied mathematics?

Q9.If you haven't studied mathematics beyond a certain level, what is the reason?

Q10. If you are totally blind/low vision till what level have you studied science?

Q11.If you haven't studied science beyond a certain level, what is the reason?

Section II. Catalogue:

Note: If you were a student and now you are a teacher and you are a person with vision impairment, so give inputs for both the situations. Otherwise give answers in the context of being a student.

Q1.What are the equipments you use to study/teach?

Q2. What are the equipments that you are aware of that are available in the market for you to study/teach?

Q3. Is there any equipment available which you do not use, why?

Q4. What are the books available for use and in which formats are they available – Braille, DAISY, E-copy, Audio?

Q5. What books are available in other formats that you do not use? Mention the formats of the books as well.

Q6.Which books do you require and are not in accessible format?

Q7.From where do you purchase / borrow the equipments?

Q8.From where do you purchase / borrow the books?

Q9. From all the equipments that you are using, which equipments do you find useful and give suitable reasons.

Q10. From all the equipments that you are using which equipments do you not find useful? Give the

Q11. Have you used Taylor Frame for algebra? How useful do you find it? If you haven't used, give reasons.

Q12. Have you used Taylor Frame for arithmetic? How useful do you find it? If you haven't used, give reasons.

Q13. Do you use Braille log books? How useful do you find it? If you haven't used, give reasons.

Q14. Do you use scientific calculator? How useful do you find it? If you haven't used, give reasons

Q15. Have you used geometry kits for totally blind/low vision? If you don't use, give reasons.

Q16. Do you use any special/mainstream equipment for practical's of science subjects? If yes, then give list of equipment along with their manufacturers and suppliers.

Q17. Have you used Nemeth Code for learning/ teaching?

Section III: Teaching Learning Techniques

Q1. Do you think the totally blind/low vision can do mathematics and science?

Q2. What are the techniques of teaching mathematics and science used in the institution to which you belong?

- How exactly do you teach (books, explaining concepts, giving exams, studying and performing experiments, writing science and maths, doing self work/practice)?
- How exactly did you learn?

Q3. Are there any unique/innovative solutions or local methods used in overcoming challenges: (eg. vedic maths/games/)?

Q4. Do you use any tactile images or 3D models for teaching and learning of science?

Q5. Do you use any tactile images or 3D models for teaching and learning of mathematics?

Q6. How do you study/teach graphs?

Q7. How do you study/teach diagrams?

Q8. What is used in handling science practical chemicals/beakers etc? Do you take any special safety measures?

Q9. Are you using any equipment for drawing geometry figures?
If yes, then what are details of those?

Q10. How do you write mathematics equations or sums, through Braille or on the computer/Taylor Frame/oral/audio?

Q11. What are the changes that you have seen over the years in terms of resources and the ease of studying and learning for the totally blind/low vision?

Section IV: Problems:

Q1. What are the problems that are faced by the totally blind/low vision to learn mathematics?

Q2. What are the problems that are faced by the totally blind/low vision to learn science?

Q3. What do you think is the reason for a large number of totally blind/low vision people being able to learn mathematics and science?

Q4. What is the teacher availability and teacher apprehensions, among teachers teaching totally blind/low vision? (Teachers teaching your child/ Special educators)

Q5. What do you think is the overall degree of interest and motivation of management, teachers and students in studying/teaching mathematics and science?

Q6. What has been the biggest hurdle in teaching/learning mathematics and science?

Q7. How do you think these problems can be overcome?

Section V: Rules and Regulations

As far as possible please send copies of university/board circulars for rules of examinations and admissions of institutions and boards.

Q1. Which board/University/Institution are you following CBSE/ICSE/ IB do you learn/ teach in?

Q2. What rules exist in your particular institution/university/board for admission for totally blind/low vision?

Q3. What rules exist in your particular institutions for examinations- theory (Maths and Science) for the totally blind/low vision?

Q4. What rules exist in your particular institutions for examinations- practical's (Maths and Science) for the totally blind/low vision students?

Q5. Do you find the existing rules effective, If not what would you want them to the rules to be?

ANNEXURE B - QUESTIONAIRE FOR MANUFACTURERS

Name of Proprietor:

Name of Company:

Address :

Website:

E-mail Address

For Manufactures of equipments for the visually impaired:

Q1. Is there a catalogue available for the complete list of products/books being produced?

Q2. Where is the catalogue available?

Q3. If there is no catalogue available then list down the products/ books being produced by you?

Q4. Are the equipments/books being produced locally or are the equipments/books being imported?

Q5. If not being produced locally, what is the reason for not producing the equipments /books locally?

Q6. How do you market your products/books?

Q7. What are the constraints that you face while producing these equipments/books?

Q8. Is it possible to locally produce equipments/books which are currently being imported, If no why?

Q9. How do you make the equipments/books available to the end user?

Q10. Which is the specific institutions that you specifically supply the products/books to?

Q11. Typically what kind of queries you get from the consumer end? Do queries come from student learners/ adult learners / working VI ?

Q12. What are the popular products internationally?

Q13. What are the popular products in India?

ANNEXURE C: USER REPORTS OF SELECT ACCESSIBLE TECHNOLOGIES FOR MATHS AND SCIENCE LEARNING

I. Accessibility VP Arithmetic, VP Algebra

Overview of the software

Developed by Henter Math, LLC., Virtual Pencil Arithmetic and Virtual Pencil Algebra are two softwares that are aimed at providing the same opportunity to a blind student as a sighted student — using a pencil to work out Mathematical problems. The only difference, however, is that these softwares involve a virtual pencil rather than a traditional pencil. These softwares utilize a virtual interface that allows a blind student to navigate and edit values, and write intermediate steps, which facilitate in obtaining the final solution. This also provides an opportunity for the teachers and graders to get to know the actual problems faced by the student, as the solution does not only consist of the final answer, but also the intermediate steps.

Availability

The software is a shareware, i.e. it is available on a limited basis free of cost. For unlimited access, payment is required (price of VP Arithmetic is US$199, while that of VP Algebra is US$399). The link to download the trial version can be found on Henter Math, LLC. website.

How it works

The software moves to the right spot on the "paper", guided by the user, and inputs the answers that the user selects. It can edit numbers and variables, insert fractions or square roots or other structures, and copy whole equations or expressions. When used with a screen reader the numbers and actions are read out aloud. The user must navigate the screen and provide the input.

The software suite currently has two products:

a. VP Arithmetic handles addition, subtraction, multiplication, and division, with fractions and decimals.
b. VP Algebra handles quantities, radicals, exponents, subscripts, Greek letters, absolute values, matrices, fractions, and many editing features.

Note that scripts developed for this program facilitate announcing special symbols as well.

Further note that many of the features that the program provides are too complicated to be used (working with fractions, for instance).

Windows 95 and later versions support the software.

Accessibility

The interface is accessible with JAWS (the software works fine with JAWS 7 and later versions). As of now, there is a bug with VP Algebra. The JAWS scripts for VP Algebra need to be modified before executing the software. An E-mail with the modified script is sent 48-72 hours after the first download.

There is no particular section of the software that is rendered inaccessible when used with JAWS. In other words, no sighted assistance is required while using the software.

The workspace cannot be navigated with the help of NVDA. Since workspace navigation is the most important step, therefore NVDA is pretty much inaccessible.

Sometimes, the first element in the workspace is announced in such a manner that it is barely audible. Nevertheless, it does not pose a substantial challenge.

Level of Mathematics supported

Pre-calculus Mathematics (excluding plane and analytical geometry) can be managed to quite an extent using this software.

Core advantages

1. This provides an opportunity to the students to use the computer just like a pencil, further providing the students in primary and middle school a hands-on experience learning Mathematics, just as their sighted peers.
2. This successfully lays emphasis on scratch work/intermediate computations which are indeed the very essence of Mathematics.

Core disadvantages

1. Except for the ability to announce the specialized symbols and notations (Greek symbols for instance), the software does not have any special feature that is not available in a standard spreadsheet software/word processor. The sense of spatial analysis extensively used in the software is of little, if no significance.
2. There are scripting issues (and compilation bugs) in the software. A person who does not understand technicalities well may not be able to manage easily.

3. The software uses a partly different interface as compared to a spreadsheet/word processor. Since Henter Math softwares will not be available during examinations, the student who extensively uses this software may find it difficult to manage on a standard word processor/spreadsheet software.
4. Navigation from one element to the next in the workspace is relatively slow as compared to navigation in MS Excel.

II. A report on LaTeX and Math ML

Introduction

LaTeX has been a widely used typesetting language for composing Mathematics and documents containing other technical content. The language naturally has a predefined syntax for generating various notations and symbols that constitute an expression. Each statement commences with a \, and Mathematical notations are enclosed within braces. However, most of the mnemonics used to denote mathematical notations are trivial, and can be easily mastered in a short span of time. At the same time, more complex the document, greater amount of sophistication will be required.

MathML is a format for presenting Mathematics and is an extension of XML format which is being widely used by the academic community and by the DAISY Consortium, besides people with technical expertise. MathML documents, when viewed on the web, in conjunction with suitable add-ins, can enhance the accessibility of Mathematical and Scientific documents to quite an extent.

Availability

LaTeX is freely available on the web at www.latex-project.org. The software is freely available, and the source code is also available for review and testing by software developers.

MathML resources may be accessed at http://www.w3.org/Math/. Many of the resources are available freely for public consumption, and some are even open source.

Accessibility

LaTeX documents are plain text files. Since the software is a plain text editor, therefore the software is accessible. The easier and more convenient approach, however, is to write only the equations and expressions in LaTeX, and accomplish the rest of the editing operations using a standard word processor (by using MathType with MS Word). In general, WYSIWYG interface is more convenient for computer users—it being true for blind users as well.

MathML content in web pages can be read to sufficient accuracy when MathPlayer is used with Microsoft Internet Explorer. However, it is imperative that this add-in is installed for accessibility features to work fine. In the absence of this additional feature, the content is rendered inaccessible.

Level of Mathematics supported

Both LaTeX and MathML support a wide range of Mathematics and Science. University Mathematics (and even beyond as per the feedback received from a few blind scientists in the US) can be managed with these softwares.

Core advantages

1. LaTeX provides a way to author Mathematics documents. Further, since it involves a character user interface, it is of great help to the blind users, as there are no chances of ambiguities.
2. Plain text editor provides for excellent accessibility opportunities.
3. MathML content (on web pages) when read aloud with MathPlayer yields good results.
4. Math Type equations, PDFs and several other Mathematical formats can be exported into MathML, and hence can be read by using Math Player (in IE)/Firefox and Opera (using MathML fonts).

Core disadvantages

1. LaTeX has several rules and a fairly complicated syntax to be mastered for a novice.
2. WYSIWYG interface presents a more pragmatic and convenient alternative.

III. Infty Editor and Chatty Infty

Overview

Infty Editor is an outstanding tool developed under the Infty project to write Mathematical equations and expressions. The interface replicates that of a text editor, allowing the user to navigate, read, insert, delete and edit mathematical equations. The user enters the Mathematical equations in LaTeX. As soon as the user hits the `\` key, the Math mode is activated, and the relevant features that facilitate insertion of equations take effect. Once inserted (which is indicated by the terminating `]` character), the software reverts to the general insertion mode, allowing to use the program just as a text editor. The best part about the software is that all expressions that are inserted are spoken out, unlike MathType+LaTeX in MS word. Chatty Infty is an extension of Infty Editor, and provides self-voicing capability.

Availability

Infty Editor is free for use, and can be downloaded from http://www.inftyproject.org/en/software.html. However, Chatty Infty is a shareware, and the trial version (as available on the website) is restricted to 15-day use.

Accessibility

Infty Editor is completely accessible, and there are absolutely no problems navigating. Chatty Infty, being self-voicing, naturally does not experience any difficulties as far as accessibility is concerned.

Level of Mathematics supported

The software can support up to University Mathematics easily. This is a favourite with several university students pursuing Math or Sciences in the United States.

Core advantages

1. Infty Editor is free, and provides blind students an outstanding way of writing Math for a blind student in a way that a sighted person can understand.

2. The interface is perhaps the easiest to use, and the most accessible.

3. Equations once written can be read unlike MathType.

Core disadvantages

1. ChattyInfty is a shareware.

IV. Writing Math and Science on a word processor: an accessibility test

Introduction

While several specialized packages are available to compose technical documents containing Mathematics and Science, it is not always very convenient to master the syntax associated with these scripting languages. Often, a better approach is to use a standard word processor, taking advantage of the symbols commonly available. This, however, has its own share of limitations.

Limitations

a. Many of the symbols commonly used in Math and Science are not read out by JAWS screen reader. This makes it difficult for the blind user to independently insert these symbols.
b. NVDA is slightly better than JAWS, but cannot be used to read symbols used in Calculus.
c. If an alternate, more accessible approach is utilized by the user (by way of writing complete words for the symbol), there is a disparity in the way the symbol is printed. The chances of ambiguity/confusion increase when a sighted user is reading the document.

Commonly used Symbols in Mathematics and Science (up to class XII- Indian Education)

Please Note: there are two ways of inserting symbols found in the symbols dialogue box.

a. **Some symbols can be inserted by using the shortcut INS+4 (note + is not to be used and simply denotes sequential keystrokes). This will pop up a list of symbols that will be read out by JAWS. Please navigate to the symbol of your choice using the arrow/direction keys, and hit the enter/return key on your keyboard.**

b. **There are several symbols that are not available in this list of a small number of symbols that pop up by using INS+4. In such a case, use INS+i (to reach insert menu), press s (to reach symbols dialogue box). A list of most of the symbols will pop up. If you use a symbol frequently, you can simply press the tab key (after invoking the symbols dialogue box) to display the recently used symbols.**

Symbol	Method of insertion	Intended purpose	Accessibility (JAWS and NVDA)
Arithmetic operators (+ and -)	Available on a standard qwerty keyboard	Standard arithmetic operators for addition and subtraction	Accessible (spoken by JAWS and NVDA)
× and ÷	Can be inserted easily using symbols dialog box (use INS+4 as the shortcut). These are not otherwise available on a standard qwerty keyboard. (*and/, available on a standard qwerty keyboard may also be used when taking notes. Use in examination is not recommended, as the evaluators may not necessarily know these symbols)	Standard arithmetic operators for multiplication and division	Accessible (read by JAWS and NVDA)

Exponents	Select the text to be superscripted, and use CTRL+shift+= ^{1}, ^{2} and ^{3} are also available in the symbols dialog box (which can be invoked using short-cut INS+4)	Used for exponents	Inaccessible (neither JAWS nor NVDA reads the powers when written using the shortcut CTRL+shift+=) JAWS and NVDA read ^{1}, ^{2} and ^{3} as `superscript 1`, `superscript 2` and `superscript 3` when inserted using the symbol dialog box. To differentiate, another alternative can be adopted-use ^ for exponents. ^ is read by JAWS (when punctuation is set to most/all). However, ^ cannot be used in work to be graded by sighted, as not all individuals may be familiar with ^ as an alternative to power (^ is used to denote exponents widely in Computer Science, but not Mathematics
Subscripts	Use CTRL+= as the shortcut after selecting the content to be sub-scripted	Widely used to name variables/constants in Mathematics and Physics; used to denote atomicity in Chemistry	Inaccessible (JAWS and NVDA do not announce that the content is subscripted) An alternative: avoid using subscripts for naming variables. Instead, use alternate alphabets to name variables.

%	Available on a standard keyboard	Percentage	Accessible (read out by JAWS and NVDA)
(…), [….], {…..}	All available on a standard qwerty keyboard	Various brackets used to denote intervals (open/close)	All accessible (though different names may be used by JAWS and NVDA)
<, >, =	All available on a standard qwerty keyboard	Relational operators	Accessible
|	Available on a standard qwerty keyboard	Vertical line	Accessible (read vertical bar by JAWS; read \`bar\` by NVDA)
°	Can be inserted using symbol dialog box (shortcut INS+4)	Widely used in plane geometry/trigonometry/calculus	Accessible
±	Can be inserted using symbols dialog box	Plus or minus (widely used in estimations)	Accessible
µ	Can be inserted from the symbols dialog box (not using the shortcut)	Used to denote 10^{-6} (widely used)	Accessible (read \`mu\` instead of \`micro\` by JAWS; read \`micro\` by NVDA)
¼, ½, ¾	Can be inserted using the symbols dialog box (shortcut will do)	Widely used in all branches of Mathematics	Accessible (read a quarter, a half, three quarters etc. by NVDA; read \`1-fourth\`, \`1-half\`, \`3-fourths\` by JAWS)
All other fractions apart from the standard fractions above	Inserted by separating the numerator and denominator by a /	Used in all branches of Mathematics	Accessible (JAWS pronounces the slash). However, it does not appear the same visually as a fraction does.

α	Inserted using the symbols dialog box (not the shortcut)	Alpha is widely used to denote standard variables/quantities; alpha rays	Inaccessible with JAWS (read by JAWS 13 while insertion- read as `Greek letter alpha` due to the labels in MS Office; read as `a` by JAWS 14 while insertion; read once inserted as `a` by both JAWS 13 and 14 which does not serve the purpose) Accessible with NVDA (read `alpha`)
γ	Inserted using symbols dialog box (not the shortcut)	Gamma is widely used to denote standard variables; gamma rays	Inaccessible with JAWS (read by JAWS 13 when inserting due to the labels in MS Office; not read by JAWS 14 while insertion; not read by any version of JAWS once inserted) Accessible with NVDA
≈	Inserted using symbols dialog box (not the shortcut)	Used to denote `nearly equal to`	Inaccessible (read by JAWS 13 while insertion due to the labels in MS Office; not read by JAWS 14 while insertion; not read once inserted; read as `symbol 34C` by NVDA)

Ή	Inserted using symbols dialog box (not the shortcut)	Used to denote `eta`, sometimes used as a substitute for `theta`; used to denote viscosity in Physics	Inaccessible with JAWS (read by JAWS 13 while insertion due to the labels; not read by JAWS 14 while insertion; not read once inserted) Accessible with NVDA
β	Inserted using symbols dialog box (not the shortcut)	Used to denote `beta`; widely used as standard variable	Partially accessible with JAWS (read by JAWS 13 when inserting due to the labels in MS Office; read as `S cet` by JAWS 14 while insertion; read `S cet` once inserted) Accessible with NVDA
Γ	Inserted using the symbols dialog box (not the shortcut)	Used to denote `gamma`; widely used as a standard variable	Inaccessible with JAWS (read by JAWS 13 when inserting the symbol due to the labels in MS Office; read as `g` with JAWS 14 when inserting; read as `G` when symbol has been inserted, defeating the purpose) Accessible with NVDA

δ	Inserted using symbols dialog box (not the shortcut)	Used to denote delta, a standard variable	Inaccessible with JAWS (read by JAWS 13 while insertion due to the labels in MS Office; read as `d` by JAWS 14 during insertion; read as `d` once symbols has been inserted, defeating the purpose) Accessible with NVDA
θ	Inserted using symbols dialog box (not the shortcut)	Used to denote theta; widely used in plane geometry, trigonometry and calculus	Inaccessible with JAWS (read by JAWS 13 while insertion due to the labels in MS Office; not read by JAWS 14 during insertion; not read by JAWS once inserted) Accessible with NVDA
ι	Inserted using symbols dialog box (not the shortcut)	Used to denote complex numbers	Inaccessible with JAWS (read by JAWS 13 while insertion due to the labels in MS Office; not read by JAWS 14 during insertion; not read once inserted) Accessible with NVDA
λ	Inserted using symbols dialog box (not the shortcut)	Used to denote lambda; widely used notation; used to denote wavelength in Physics	Inaccessible with JAWS (read by JAWS 13 while insertion; not read by JAWS 14 during insertion; not read once inserted) Accessible with NVDA

π	Inserted using symbols dialog box (not the shortcut)	Used to denote pi; widely used in trigonometry	Inaccessible with JAWS (read by JAWS 13 while insertion; read as `p` by JAWS 14; read as `p` once inserted, defeating the purpose) Accessible with NVDA
σ	Inserted using symbols dialog box (not the shortcut)	Denotes submation/sigma	Inaccessible with JAWS (read by JAWS 13 while insertion; read as `s` by JAWS 14 during insertion; read as `s` once inserted, defeating the purpose) Accessible with NVDA
ϕ	Inserted using symbols dialog box (not the shortcut)	Denotes fi; a standard variable; denotes phase difference in Physics	Inaccessible with JAWS (read by JAWS 13 while insertion; read `f` with JAWS 14 during insertion; read `f` once inserted, defeating the purpose) Accessible with NVDA
℮	Inserted using symbols dialog box (not the shortcut)	Denotes estimation/approximation	Inaccessible with both JAWS and NVDA (read by JAWS 13 while insertion; read `e` by JAWS 14 during insertion; read `e` once inserted; not read by NVDA)

∂	Inserted using symbols dialog box (not the shortcut)	Denotes partial derivative (calculus)	Inaccessible with both JAWS and NVDA (read by JAWS 13 while insertion; not read by JAWS 14; not read once inserted by either of the softwares)
√	Inserted using symbols dialog box (not the shortcut)	Denotes radical sign	Partially accessible with JAWS (read by JAWS 13 while insertion; read as \`v\` by JAWS 14 during insertion; read as \`v\` once inserted) Partially accessible with NVDA (reads the radicle as \`square root\`) Note: Students can easily understand that if \`v\` proceeds a numeric quantity, it implies a radicle sign. However, \`square root\` as read by NVDA presents problems.
∞	Can be inserted using symbols dialog box (not the shortcut)	Denotes infinity; widely used in calculus (especially while computing limits)	Partially accessible with JAWS (read by JAWS 13 while insertion; read as \`8\` by JAWS 14 during insertion; read as \`8\` once inserted) Accessible with NVDA Note: even if JAWS reads the symbol as \`8\`, its implication can be understood by context

∟	Can be inserted using symbols dialog box (not the shortcut)	Denotes right angle; used in plane geometry	Inaccessible with both JAWS and NVDA (read by JAWS 13 while insertion; not read by JAWS 14 during insertion; not read once inserted; not read by NVDA)
∩	Inserted by symbols dialog box (no shortcuts)	Denotes intersection; used in set theory	Partially accessible with JAWS (read by JAWS 13 while insertion; read as \`n\` by JAWS 14; read as \`n\` once inserted) Note: The implication of this symbol can be understood by context Inaccessible with NVDA (symbol not read)
∫	Inserted using symbols dialog box (no shortcuts)	Denotes integral sign; used in Calculus	Inaccessible with both the softwares (read by JAWS 13 while insertion; not read by JAWS 14 during insertion; not read by either of the softwares once inserted)
≠	Inserted using symbols dialog box (no shortcuts)	Denotes \`not equal to\`; used as a relational operator	Inaccessible with JAWS (read while insertion by JAWS 13; not read by JAWS 14 during insertion; not read once inserted) Accessible with NVDA (read \`not equal to\`)

≡	Inserted using symbols dialog box (no shortcuts)	Denotes `identical to`; used as a relational operator	Inaccessible with JAWS* (read by JAWS 13 while insertion; read as `=` by JAWS 14 when being inserted; read as `=` once inserted) Note: Since JAWS reads the symbol as `=`, it is misleading. Inaccessible with NVDA (not read)
➔	Use =, = and > in this order	Used as `tends to` in Mathematics (calculus); reaction arrow in Chemistry	Partially accessible (JAWS reads the symbol as `symbol 232`. While the actual symbol is not properly read, the student may note that symbol 232 represents the arrow, and may work accordingly) Inaccessible with NVDA (the symbol is read similar to (, and hence is misleading)
∴	Use ALT+8756	Denotes `therefore`	Inaccessible with JAWS and NVDA (not read)
≡	Use ALT+8801	Denotes congruence; used in plane geometry	Inaccessible with JAWS (read `=`) Inaccessible with NVDA
Ø	Use ALT+8709	Denotes empty set	Inaccessible with JAWS (read by JAWS) Inaccessible with NVDA (not read)
□	Use ALT+2286	Denotes subset; used in set theory	Inaccessible with JAWS and NVDA (not reading)

Observations

a. As of now, several symbols widely used in Mathematics and Science are inaccessible with JAWS. While some of the symbols are not read, there are yet others that are read inappropriately. Some, on the other hand, are read in such a way that they may cause confusion and may mislead the user.
b. NVDA is a lot better when it comes to reading the symbols. However, several symbols as used in Calculus and higher level Mathematics are still rendered inaccessible.

Recommendations

a. Freedom Scientific should be contacted to get more information on the work that the organization is doing. It will be good if we can bring our concerns to them, so that scripts enabling JAWS to speak these symbols outside the `symbol dialog box` can also be developed. It seems that the Freedom Scientific testing committee is doing some work, trying to enhance accessibility. The concerns, if reported, may be addressed in the upcoming releases of JAWS.
b. Since NVDA is an open source, the source code is freely available. Developers may get some useful information as to how several symbols have been made accessible. This information can be used by developers to develop scripts, which when embedded in JAWS, can facilitate reading of these symbols.

Alternate strategies

a. Adding the symbol to JAWS dictionary file: Certain settings can be made such that JAWS pronounces a symbol as another word specified by the user. Follow the following steps:

i. Insert the symbol which is not being read out by JAWS.
ii. Press INS+F2.
iii. Press D and reach `dictionary manager`. Hit enter/return key.
iv. Press CTRL+shift+D.
v. Tab to the `add` button, and press enter.
vi. Tab to the field `actual word`. The original symbol will pop up.
vii. Tab to the `replacement word`. Spell out the symbol name.
viii. Tab to OK button and press enter. Close the dictionary manager and choose `yes` when prompted for saving changes.

b. Using autotext:

Writing equations

Symbols are the building blocks of an equation. However, a symbol has practically little, or in fact no significance unless it is put to use in writing equations or in computations. This section seeks to examine how this can be achieved.

a. Place your cursor at the beginning of the line.
b. If the equation or the expression begins with an alphabet, simply type it out just as you would have normally typed it in a plain text document. Similarly, if the first element in the expression/equation happens to be a symbol, simply insert that symbol (using the techniques described above).
c. Now, repeat step (b) for all of the elements in the equation until you encounter an over (upon) sign, i.e. you encounter a denominator.
d. To make sure that the entire forthcoming text is construed as denominator, enclosed it in parenthesis (.....).
e. If half of the text is denominator, and the text following it is the numerator, enclose the text (the denominator and the numerator proceeding it) in one big bracket, separating the two by enclosing each in separate small brackets. Subsequently, separate the denominator and the text of the numerator following it by enclosing the text of the numerator following the denominator in yet another big bracket.

e.g.

Consider an expression

Numerator A+B with denominator C+D, followed by numerator E+F

Same as:

Numerator A+B with denominator C+D, times, numerator E+F

This will be typed out as:

[(A+B)/(C+D)][E+F]

f. If the denominator contains two or more separate terms, enclose all of those terms in big brackets ([....]), and then enclose each separate term in small brackets (parenthesis).

The following illustrations CONSOLIDATE ALL THE METHODS DESCRIBED ABOVE.

Illustration1

To type Einstein's mass-energy equivalence $e=mc^2$

a. Type the first element e.
b. Type the second element = (available on a standard qwerty keyboard).
c. Type the third element m.
d. Type the fourth element c.
e. Type the fifth element ² (by inserting ² using the methods described above).

Illustration 2

To type I=numerator with eE, denominator with m, followed by numerator tau (denoting time constant)

a. Type the first element I.
b. Type the second element =
c. Now, enclose the first fraction in big brackets ([.....]).
d. Enclose the numerator in brackets. So, type (Ee).
e. Separate the numerator and denominator by a /.
f. Since the denominator is a single element, you may or may not enclose it in small brackets. For simplicity, let us enclose it in small brackets.
g. Now that one of the fractions has ended, close the first fraction with a big bracket or].
h. Enclose the second fraction (consisting of just the numerator, implying unity in the denominator) in a second big bracket.

Handing in homework/assignments for grading

Homework and assignments can be written on a word processor in the following way.

a. Using the methods described above (both insertion of symbols and writing equations), write your text document containing Math and science just as any other text document.
b. Only use line feeds (press the enter/return key) when you want to go to the next line. Do not use it, for instance, to denote denominators/subscripts etc.
c. For symbols not readily available to you (due to inaccessibility with the screen reader being used), you can substitute those symbols with complete words for those symbols.
d. If you have sighted assistance later on, you may replace particular words you used in lieu of the symbols with the corresponding symbols using the `replace all` feature available in notepad/MS Word.

e. If you do not have sighted assistance, you may want to consult your teachers for permission to use complete words denoting the symbol in lieu of the symbol.

Managing scratch/rough work/calculations

The following are a few methods to manage scratch work/rough work/calculations.

a. Use a Taylor Frame
b. Use an Abacus: Abacus is a handy device that enhances quick calculations. However, this does not work effectively when working /using high level Mathematics such as derivative, integrals, analytical geometry, etc.
c. Use a calculator: Some educational organizations and school boards permit the use of a calculator. You may want to check the norms/policies in respect of your board/organization. If calculators are permitted, you may either use talking calculators, or may even use the scientific calculator (provided as a part of the Windows OS). You can also use calculators on handheld devices such as mobile phones, PDAs and so on.
d. Use spreadsheet: Spreadsheets can be used for facilitating calculations in the following two ways:
i. Use the auto-calculate feature: Where calculators are permitted, you can use the auto-calculate feature of MS Excel to perform calculations. This employs Excel formulae to perform calculations. For a more rigorous treatment of this topic, consult an Excel tutorial widely available online.
ii. You may perform calculations on a spreadsheet without using the auto-calculate feature. Adopt the following course of action:

1. Position your cursor on cell B2 (this will change for the nature of computations, and the user must make an intelligent choice). The cursor has been positioned in cell B2 to facilitate carry overs/borrows (used in addition and subtraction) and computation of products involving more than one digit.
2. Type one single digit in each of the cells.
3. Hereafter, perform addition and subtraction just as you did on the Taylor Frame. There is no need to write the operator, however, and it is advised to keep track of it as you progress.

Illustration

The spreadsheet below shows the sum of 256 and 529.

	1	
2	5	6
5	2	9
7	8	5

V. A report on Math Type, Math Player and Math DAISY

Overview

Design Science, Inc. is the maker of several software packages to read and write Mathematics and Science. A few of the softwares manufactured by the organization include Math Player, Math Type, Math DAISY, among others. This report seeks to examine the accessibility of these three software packages.

Math Type is a WYSIWYG editor that has gained widespread momentum to write Mathematics. This is primarily due to the flexibility of not mastering the code associated with scripting languages such as LaTeX. Unfortunately however, such a change has not been seen among the blind community. Math Type is not quite accessible when it comes to writing Mathematics. It may be noted, though, that Math Type can ease writing Mathematics quite a lot. Rather than using LaTeX to compose complete documents and learning all the commands associated with the software, one can easily master LaTeX Mathematical commands (to write Mathematical equations using LaTeX), and then use the Math Type features in MS Word (once Math Type is installed) to easily format the rest of the document just like any other word processing document. In short, Math Type has not benefited the blind community to that extent as it has benefited the sighted, but has definitely made it more comfortable for all.

Math Player is a plug-in developed by Design Science, which when used with IE, renders MathML documents converted into web pages accessible. This is of great utility, as several softwares allow the conversion of various Mathematical formats into MathML web page. For instance, LaTeX documents can be converted into MathML using tex4ht, Chatty Infty and Scientific Notebook.

Math Daisy™ enables teachers and others to save documents in the DAISY Digital Talking Book format. Students can use Math Player™-enabled DAISY player software to read classroom materials in the manner that suits their abilities and preferences best. Math Daisy works with Microsoft Word, Microsoft's Save As DAISY add-in, and MathType. As one might guess from its name, Save As DAISY adds a "Save As DAISY" menu item to Word's File menu. This command saves the document as a DAISY Digital Talking Book ready to be used in an eBook reader. Math Daisy enhances the Word-to-DAISY conversion process, converting the equations in the document to MathML as required by the DAISY format.

Availability

A 30-day trial version of Math Type and Math Daisy can be downloaded from Design Science's website. The softwares are shareware, and the permanent versions need to be purchased.

On the other hand, Math Player and `Save as DAISY` add-in are freely available on the web. Office 2010 also includes a `Save as DAISY` option.

Accessibility

a. Writing Mathematical equations using MathType is inaccessible. However, writing Mathematics as LaTeX statements and then converting them into the corresponding MathType equations are indeed very useful, as this process necessitates learning only the LaTeX commands associated with Math mode. This is contrary to the conventional approach, wherein entire documents were written in LaTeX. This meant mastering not only the Mathematical commands, but also other formatting commands.

b. MathPlayer is a great tool that enhances the accessibility of Mathematical content. When trying to read Mathematical webpage using IE in conjunction with Math Player, most of the content is pretty much accessible.

c. MathDAISY is yet another software from Design Science that furthers accessibility of Mathematical content by facilitating the conversion of electronic documents into their corresponding DAISY documents.

Level of Mathematics supported

The softwares support a wide range of Mathematics, well beyond university Mathematics. Plane geometry, however, remains a concern.

Core advantages

1. Since LaTeX is a plain text language involving statements and rigid syntax, it is difficult to master all the languages commands including those associated with formatting. Using MathType necessitates learning of only those commands associated with Math mode, thereby lessening the effort.

2. If MathType is used for creating textbooks and the electronic copy is provided to a blind user, a simple keystroke (ALT+backslash) can convert all the MathType equations into their corresponding LaTeX, thereby enhancing accessibility.

3. Math Type documents can also be converted into the corresponding MathML, thereby providing a way to make the text accessible (using Chatty Infty, Scientific Notebook, Math Type or Tex4HT).

4. MathDAISY offers a wonderful way of converting documents containing Mathematics into DAISY — a format gaining widespread momentum across the globe.

Core disadvantages

1. Math Type and Math DAISY need to be purchased.

2. Conversion of Mathematical documents into the supported formats do not yield 100% accurate results. In fact, more technical Mathematics documents (containing determinants and Calculus both, for instance), when converted, resulted in very poor output.

3. MathType, despite being WYSIWYG, still requires a blind person to know LaTeX.

VI. Accessibility of InftyReader

Introduction

The InftyReader OCR application is an optical character recognition software that effectively recognizes technical content containing Mathematics and Science. The software properly recognizes scientific documents scanned from paper and can also effectively recognize documents in PDF format. InftyReader recognizes complicated math expressions, tables, graphs and other technical notations and converts them to accessible formats. The software can be used by people with print disabilities in combination with the ChattyInfty accessible Scientific Editor application. ChattyInfty provides speech access for reading and writing math and editing the output of InftyReader. Sighted people can use InftyReader with the free Infty Editor to edit InftyReader output and produce accessible scientific content.

Availability

InftyReader and ChattyInfty are made by the Infty Project and are sold through Science Accessibility Net. A trial version of the software can be downloaded from Science Accessibility Net located on the web at http://www.sciaccess.net/en/. The full version of the software needs to be purchased through Science Accessibility Net.

Salient features

- It uses the "ExpressReaderPro", OCR engine from Toshiba Corporation and the "WinReader" OCR application from MediaDrive Corporation simultaneously to recognize characters in regular text. The latest version of the software when purchased also has an add-in that can work in conjunction with ABBYY Fine Reader.
- It uses an OCR engine developed by Infty to recognize math and scientific formulas.
- It can recognize tables containing math expressions.

- It can convert black and white scanned documents and PDF files.
- It recognizes individual pages in a PDF file.
- The output generated after processing can be in one of several available formats including IML, LaTeX, Hr-TeX, XHTML+MathML and even Microsoft Word 2007 (XML).

Level of Mathematics supported

The software supports a wide range of Mathematical and Scientific content, including high school and university Mathematics. Particularly, the software works well with algebra, statistics, analytical geometry and calculus.

Accessibility

The software has an accessible interface, and there are no problems as such when navigating through the various options and menus. The software allows great flexibility and customization to enhance the quality of output, which can be effectively used to one's benefit. For instance, specifying the level of mathematics and indicating the DPI (dots per inch) level can help improve the quality of output. Use `high school mathematics` as the level of Mathematics whenever possible, as it yields better results.

Core advantages

1. The software can effectively be used to make a wide amount of printed technical content accessible with a great amount of precision.
2. Documents in Portable Digital Format (PDF) can also be converted into accessible documents using this software.

Core disadvantages

1. Great care must be adopted while scanning the document. Several instructions (regarding paper placement, DPI level, colour and so on) need to be religiously followed to ensure optimum results.
2. The permanent version of the software is expensive to be used by an individual in India
3. There is great variation in the results obtained on scanning the document.

Some useful information

1. The software documentation available online recommends scanning the document as a TIFF or GIF, and then converting it to the accessible versions later. The results obtained, however, after following this route are not satisfactory.
2. Alternatively, the document may be scanned as a PDF (using Fine Reader), and then exported to MathML. The results are somewhat better.

VII. Accessibility of graphing tools: Audio Graphing Calculator and Math Trax

Introduction

Getting an intuition of graphs has always remained a big challenge for the visually challenged. While tactile graphs present one solution, it is not always very convenient and easy to produce tactile graphs. Similarly, some students may also prefer verbal descriptions of graphs and auditory representations (tonal representation) of graph over tactile representation. The following are two softwares that seek to achieve this objective:

a. Audio Graphing Calculator developed by ViewPlus Technologies
b. Math Trax developed by NASA

Math Trax not only returns a verbal description of the graph corresponding to the equation of the curve entered by the user, but also provides a tonal representation (variation of frequencies). Similarly, AGC provides the tonal representation as well. While the tonal representation does not provide a lot of contextual information, it provides a basic idea of the monotonicity of the curve. This information about the monotonicity immensely helps the students especially when dealing with application of Calculus.

Availability

a. Audio Graphing Calculator is a shareware, i.e. is available for free download on a limited basis. Only the trial version of the software (30-day trial version) is available for free download from http://www.viewplus.com. An activation key (serial number) needs to be purchased for the full version of the software.
b. Math Trax is a freeware, i.e. can be freely downloaded from NASA's website located at http://prime.jsc.nasa.gov/MathTrax/. In fact, NASA welcomes feedback from end users, and also is willing to share the source code for further development and improvements.

Accessibility

Both the softwares employ an accessible and screen reader friendly interface.

a. The interface employed by AGC is slightly complex and complicated for a first-time user. While the `readme file` describes the options clearly, navigation can prove a slight concern for a person having very little familiarity with Computers. Once the menu options are understood clearly, accessibility is not a concern.
b. Math Trax is easy to use, and does not have any accessibility challenges as such.

Both JAWS and NVDA can be used with both of the softwares without major problems.

Level of Mathematics

Both the softwares support graphs and curves that are used until Class XII Mathematics. Therefore, these softwares can easily be used when working with graphs/curves until class XII. A blind student from California reports Math Trax to be of great help even in the university mathematics courses. It can, therefore, be broadly inferred that these softwares work well until the introductory university Mathematics courses.

Some important notes

The following may please be noted about the two softwares:

a. The verbal descriptions of the curve provided by Math Trax is more helpful than that provided by AGC.
b. The tonal representation is more clear and informative in case of AGC. The software also provides several options to customize the tonal representation, using such options as time, range of frequencies, and other special sounds to denote origin, etc.

Core advantages

a. These softwares provide important and useful information to a blind student who does not have access to a tactile graph, or who prefers instruction in electronic format.
b. These softwares can help in understanding the concepts of range, monotonicity, domain, codomain, etc. associated with a function and its curve.
c. AGC and Math Trax also allow a graph to be generated based on the equation of the curve. This can be used by the blind student who cannot draw the graph otherwise.
d. The graph can also be generated using data set provided by the user.

Core disadvantages

a. AGC is a shareware, and hence needs to be paid for.
b. Representation of curves in Economics and statistics (such as the bell-shaped curve used in mean and standard deviations and such topics) and their appropriate and relevant descriptions has not been addressed.
c. Although the verbal description provided by Math Trax is of immense help, it sometimes does not provide the particular information which is required the most for solving that particular problem (asymptotes, for instance).
d. Incorporating these softwares (particularly their features) in a standard word processor or spreadsheet using an add-in may help.

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This report is based on research conducted by the Xavier's Resource Centre for the Visually Challenged (XRCVC) as part of the Tech Mahindra Foundation's Vision for India (VFI) Project

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