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Effect of Digital Mode for Learning Algebraic Formulae among Students with Visual Impairment

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ABSTRACT

Digital technologies propelled Math education rapidly in recent decades. In secondary school math curriculum, algebra is a core topic. There are limited resources for students with visual impairment in the academic field particularly subject like Math that are with symbols, and formulae. With this premise, the study aimed to develop Digital Mode for Algebraic Formulae and study its effectiveness by introducing the Digital Mode to students with visual impairment. The study adopted experimental method involving 53 students with visual impairment. The Digital Mode developed is a web-based tool which conveys meaning of Algebraic Formulae that are visually oriented and thus its reading mode ensures interpretation of formulae. After introduction of Digital Mode for Algebraic Formulae to the visually impaired students, the results showed a significant improvement in learning Algebraic Formulae in this experimental study. Therefore, the study indicated that Digital Mode is efficacious for learning Algebraic Formulae among students with visual impairment.

Keywords: Visually Impaired, Digital Mode, Algebraic Formulae, Inclusive Schools and Special Schools.

INTRODUCTION

In today's education, digital learning is a prominent focus in education especially for math subject. Digital learning concept is accepted at every level of education (Mulenga & Marbán, 2020; Viberg et al., 2023). Integration of technology in educational system has an impact on students' performance (Huda et al., 2024; Vázquez-Cano et al., 2020). (Karageorgou, 2022): Digital Mode of learning insist that teachers to have digital competencies necessitating them to be responsive to change, from conventional teaching to digital teaching style.

Mathematics education has undergone radical changes in recent decades, and this is propelled by rapid digital technologies. The once familiar landscape of mathematics teaching-rote memorization, drill exercises, and blackboard instruction is increasingly being supplemented, even revolutionized, by the incorporation of digital tools and platforms. This shift brings with it both opportunities and challenges for educators, students, and policymakers alike. In education, the beginning of digital technologies is meteoric, reaching unparalleled proportions over the last three decades with digital learning platforms, online lessons, and educational software, now a core part of today's classroom (P Drijvers, 2019; Paul Drijvers, 2019). This trend was accelerated by the COVID-19 pandemic, in which technology took a central place in remote learning environments, forcing educators ahead to adapt at a much quicker pace to digital tools in that period (Bokhove & Drijvers, 2010). In the process,

education has become irrevocably altered, and an urgent need has been developed to connect the gap between traditional teaching methods and modern approaches based on technology.

Research work on digital education in subjects like math has increased significantly and the resources are always up to date. The use of digital tools in mathematics education raises some critical questions about the types of digital tools to be used for different math concepts and their overall effectiveness (Engelbrecht & Borba, 2024)

In secondary school math curriculum, algebra is a core topic. Algebra is vital either to advanced study or to professional work in today's society (Katz, 2007; Kendal & Stacey, 2004). Mastering algebra is crucial for students' futures all over the world. In algebra education, ICT use contributes significantly to its learning and teaching (Rakes et al., 2010). For example, use of digital tools in algebra education can promote students' development both of symbol sense and of procedural skills (Bokhove & Drijvers, 2010).

Due to absence of vision, people with visual impairment use touch and hearing sense to gather information in the environment. These senses cannot fully compensate for the absence of vision and hence visually impaired and blind people experience difficulty in learning and gather information in the environment.

RATIONALE OF THE STUDY

Mathematics has been recognized as a "formidable road block" for students with visual impairment (Gulley et al., 2017) High-school math subject is a gateway for students to learn and progress in social and professional worlds. With technological advancements, ICT has provided many educational tools. The educational tools in general include computer softwares, graphic calculators and web application for virtual learning. (Kleanthous & Meletiou-Mavrotheris, 2018). However, visually impaired students face difficulty to process visual cues and difficulty in acquisition of mathematical formulae. This drawback leads to a significant knowledge gap between visually impaired and nondisabled students. According to the U.S. Department of Education, as mentioned in (Blackorby et al., 2003), "15% of all visually impaired students are five or more grade levels behind their sighted peers. This knowledge gap leads to a staggering unemployment rate among disabled individuals. Although ICT has improved the productivity of people with a physical disability, there are limited resources for Visually Impaired students in the academic field" (Ashraf et al., 2016). With this premise, a study was attempted with twin objectives: to develop Digital Mode for Algebraic Formulae and study its effectiveness by introducing it to the students with visual impairment.

REVIEW OF LITERATURE

(Yoon et al., 2012) reported that digital learning was first proposed by Jay Cross in 1999. Digital or E-Learning has different explanations and terminology. They are web-based training, online learning and network learning.

(Yoon et al., 2012) regarded digital learning as delivery with digital forms of media through the Internet. Digital learning improves teaching effectiveness and to enhances knowledge and skills. Computers and network technology media were used in learning environment including synchronous and asynchronous learning in learning. It breaks through the restrictions on "time, location, and schedule, and to achieve the learner-centred individualized learning". (Kaklamanou et al., 2012).

The objectives of the study on "A Pilot Study of a Self-voicing Computer Program for Prealgebra Math Problems" by (Beal et al., 2011) are to field-test the accessibility of a self-voicing computer program: Fourteen Visually Impaired students working with prealgebra math problems were involved in the study. The programme provided the participants with audio output for word problems. Participants interacted with the program with keyboard keys. The study was not designed to assess the participants' algebra skills, but how the participants use audio clues to solve the problems. The findings showed that the audio materials could be useful resources for students with visually impaired in learning math.

(Bouck et al., 2013) in their study aimed at evaluating the impact of "eText player ReadHear" to understand and access algebraic expressions. The interactive approach was adopted in the study: The eText player provides algebraic expressions in speech format. The result of the study reveals that students effectively used the technology to access algebraic expressions.

The application "Math Melodies": supports primary level students with visual impairment in Learning Math (Ahmetovic et al., 2017). The aim of the study is to teach basic mathematics to primary school students using an iPad application. Three blind and two sighted students participated in the study. The interaction approach used in the study are, the application is accessible for blind students through a screen- reader and a simplified on-screen keyboard to answer questions. The findings are Participants were able to interact with the system and found the application entertaining and accessible. The application helps visually impaired students explore audio-visual

elements on a touchscreen and provides immediate feedback. This application keeps visually impaired students engaged and entertained.

The purpose of the study is to investigate the use of earcons, sonification, and speech synthesis to learn mathematical functions and graphs. Audio Functions provides verbal and musical earcons on graph exploration. Graph as an Interactive approach. Verbal messages are used to convey information upon request. Users may interact with the application using a keyboard, mouse, touchpad or touchscreen. The application is available on mobile devices, PCs and all browsers. The findings indicated that the participants effectively used the system and explore the presented graphs. Six students preferred a touch- screen and five students appreciated the touchscreen and touchpad/mouse interaction equally. (Ahmetovic et al., 2019)

The purpose of the study is application of Mobile App to teach visually impaired students math Braille and help in mathematical calculations. Twenty visually impaired participants expressed that mobile application improves functionally. Participants can interact with the application through a touch screen and the application provides audio and vibrational feedback to help the user make a decision. The application evaluation by the students, teachers and experts. It suggests that vibrational and voice feedback can assist students to learn Nemeth code. (Mathematical Code using Braille dots) (Nahar et al., 2022)

In the study on "Adaptable Accessibility Features for Mathematics on the Web" conducted by (Cervone & Sorge, 2019) is a web based tool enabling math formulae on the web display. The work is implemented in the MathJax library with new personalizing features. This package offers outputs in tactile and audio making it accessible to screen readers. It provides tactile and speech to support screen-reader users and provides visual aids to maximize accessibility on the web. The study results are MathJax provides aural rendering for mathematical expression, which can be generated on the fly when running in the pre-computed or web browser by the author. MathJax offers various features such as formula coloring, highlighting, contrast, and magnification to increase the accessibility of math formulae on the web.

(Ahmetovic et al., 2018), in their research developed a "LaTeX" package which provides accessibility of mathematical formulae in PDF documents. Four students with visual impairment participated in the assessment of this study using Acrobat DC PDF reader. The package facilitates the creation of accessible PDF documents by inserting unknown replacement text for math formulae using ActualText PDF attribute. This makes it visible to screen readers and braille bars Interaction approach was used in the study. The participants correctly read math formulae inside PDF documents produced using Accessibility.

(Arooj et al., 2020) developed a Web-ALAP. It is a web-based LaTeX editor. It provides speech-based prompts and automatic narration of the error messages. It also offers a "Math Mode" that gives a natural language narrative of the math content within the document. Interaction Approach was used. Web-ALAP offers a comprehensive set of keyboard and shortcut keys to maximize accessibility and easier navigation for math equations. A web-based LaTeX editor is equipped with accessible debugging features for real-time auditory feedback. Ten students with visual impairment participated in the study. The result showed that the user appreciated the "Math Code" of the web. All participants recognized the importance of being informed through audio feedback.

"The MathSpeak is a non-ambiguous language for audio rendering of MathML. In this study the authors introduced a new method which provides audio-rendering of complex mathematical formulae in MathML. Results of the study indicated that while presenting mathematical terms in non-visual format, it may lead to multiple interpretations. With MathSpeak technology, authors enabled the rapid translation of STEM material into MathML format and eventually into a non-ambiguous speech format". (Sheikh et al., 2018)

The study aimed at improving the accessibility of mathematical formulae with the help of natural language processing explanations for about 420,000 math formulae from Wikipedia's repository. It provides Graphical representation of math formulae. This study introduced the MathAcc which is an assistive technology designed to help visually impaired students gain access to the graphical representations of complex math formulae published on Wikipedia. (Fuentes Sepúlveda & Ferres, 2012).

OBJECTIVES OF THE STUDY

1. To develop Digital Mode for learning Algebraic Formulae among students with visual impairment
2. To study the effectiveness of Digital Mode on learning of Algebraic Formulae by students with visual impairment

METHOD

Site Selected

The study was conducted in 4 districts of Tamil Nadu which include Coimbatore, Madurai, Salem and Trichy. Visually impaired students studying in Grade VIII were selected as study sample.

3.2 Selection of the Sample

The sample comprised of 53 students with visual impairment with 34 Boys and 19 Girls. A stratified random sampling technique was adopted to select the sample with these exclusion criteria: a) visually impaired children studying at primary and secondary level, b) visually impaired children with additional disabilities, c) the children of those parents who have not given consent to include their wards in the study, d) drop out students and e). those children who initially involved in the study but were long absent afterwards. The total number of the sample selected was 56 and out of this, 53 students with visual impairment were finally selected. The below table presents the distribution of sample:

Table 1: Distribution of the Sample

Sl. No	Demographic Variables	Categories	Number	%	Total %
1	Type of School	Special School	39	74	100
		Inclusive School	14	26	
2	Gender	Male	34	64	100
		Female	19	36	
3	Nature of Disability	Totally Blind	25	47	100
		Low Vision	28	53	

Among them, a majority (74%) were from special schools, and 26% of them from inclusive schools. Among the sample, 64 % of them were male and 36% of female visually impaired students. Based on the nature disability, 47% were totally blind and 53% with low vision.

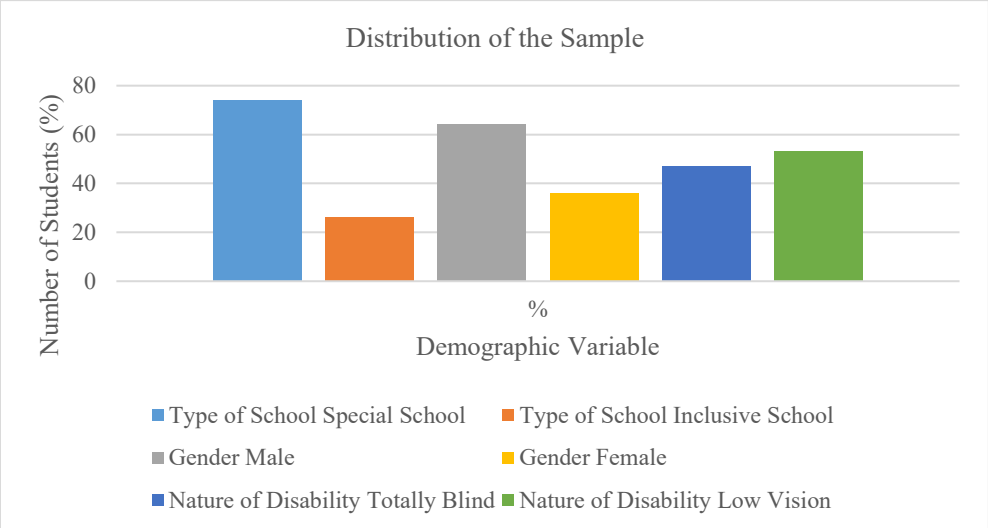

Figure: 1 Distribution of the Sample

Stage: 1

Development of Digital Mode for Learning Algebraic Formulae

Visually impaired students in general use screen readers to access digital content, even for Math learning and thus they rely on screen readers. However, today's digital world, the screen readers like NVDA (Non-Visual Desktop Access) has its own limitation, since screen readers do not convey meaning of math content such as formulae, equations and symbols. Screen readers in general are useful to learn subjects like Arts, Literature or history.

To bridge the gap and facilitate Math learning content, Digital mode has been developed for learning Algebraic Formulae. Digi mode is a web-based tool addresses the challenges in learning Algebraic formulae. This digital mode effectively conveys meaning of algebraic formulae which are visually oriented and thus its' reading mode ensures interpretation of formulae. The interaction mode helps the user learn the formulae, and practice, and evaluate their learning content. The system displays the content both in Print and Braille format. It reads the content with pauses to understand the context in a better way. The interaction mode enables the user to zoom in and zoom out of the formulae with auditory feedback. Before entering into the Digital Mode, it is designed to tutor the prerequisite skills such as Mathematical Code, numbers, alphabet, basic signs and symbols in Braille format.

Digital mode has an additional feature and can be downloaded by anyone who needs this tool for Algebraic formulae. The developed tool acts as a translator converting the Algebraic formulae both in Braille and Print format for application by visually impaired students and sighted teachers. The teachers can review the math performance of the students with the help of the Print format simultaneously displayed with Braille format. The Digital Mode system is developed with inclusivity in mind benefiting all students who need accessibility support.

Pilot Study

The pilot study was conducted when the digital mode was ready for use. For this purpose, a total of 90 special teachers for the students with visual impairment and student teachers were oriented to the functionality of the system mostly individually or a maximum of three teachers in a group. The digital mode for algebraic formulae has been assessed with the help of Special Teachers and Student Teachers. After the demonstration, a rating scale eliciting responses for the seven major components such as i) Digital Learning Tool helps learning basic Math Braille ii) Self-Learning Tool iii) Usability iv) Scope of the digital mode on learning algebraic formulae and v) Challenges of the digital mode. The tool has been administered to 34 student teachers and 25 Special Education teachers along with the system. The feedback received from the special teachers and student teachers contributed to refine the digital mode on the execution window. The result reveals that the tool was highly reliable and the score of Cronbach Alpha is 0.88.

Stage: 2

Study the Effectiveness of Digital Mode on Learning Algebraic Formulae

After the development of the digital mode on learning Algebraic Formulae, its efficacy was analysed with the introduction of the tool to visually impaired students. For this purpose, samples have been selected and the procedure for finding out the effectiveness of the system is detailed below:

Design of the Study

The design adopted in the study is a Quasi-Experimental design. It is a single group design. Here Pre observation/tests and Post observation/tests were made besides Treatment. The layout of the design is:

O1× O2

Here O1 is Pre observation

O2 is post observation

× is the treatment in the Experimental study.

Construction of the Tool

Personal Data Bank

To collect general information regarding Gender, Grade, and Type of School, a personal data bank was developed.

Tool to Assess the Level of Acquisition of Algebraic Formulae

The probes related to Algebraic formulae were in two aspects: Basic Formulae and Advanced Formulae. The investigators provided the test in Braille and dictated the probes if the students were not knowing Braille and Mathematical Code (also known as Nemeth Code) for formula expression. A total of 7 Algebraic Formulae were provided for assessment. Each identity formula was tested for assessment purpose. The tool was given in three formats: Braille, Print and Large Print (14 – 18 size). A '2 score' was given for correct response and "Zero" score for incorrect response. The duration of three month was spent for intervention and data collection. The Algebraic Formulae were included in the study are "$(a+b)^2 = a^2+2ab+b^2$; $(a-b)^2 = a^2-2ab+b^2$; $(a+b)(a-b) = a^2 - b^2$; $(x+a)(x+b) = x^2 + x(a+b) + ab$; $(a+b)^3 = a^3 + 3a^2b + 3ab^2 + b^3$; $(a-b)^3 = a^3 - 3a^2b + 3ab^2 - b^3$; $(x+a)(x+b)(x+c) = x^3 + (a+b+c)x^2 + (ab+bc+ca)x + abc$"

Implementation of the Intervention

The intervention was given to students with Visual impairment in four major areas:

1. Orientation to Concepts of Algebraic Formulae

The orientation was given for nearly 4 hours. The components include, Definition of Algebra, concept of Variables, Constants and Coefficient and usage of Nemeth codes (Mathematical code used in Braille) with rules.

2. **Introduction of Computer and use of Computer keys for operation**

To replicate using a braille machine, the existing computer keyboard was used by installing Duxbury Braille software. Duxbury Braille Software is a software program that converts electronic documents to Braille. Six-Key Entry allows to use six keys on regular PC Keyboard, plus the space bar, to input braille directly into Duxbury Braille Translator.

The keys correspond to the braille dots as follow:

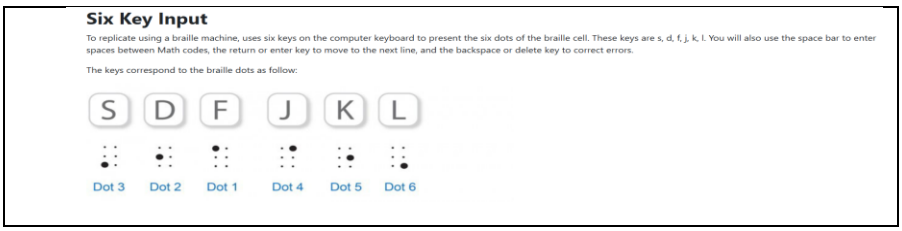

Figure 2: Six Key Input

Keyboard finger placement

The left-hand index finger will use letter 'f' for dot 1 of the braille cell, with 2nd and 3rd fingers of the left-hand using letters 'd' and 's' for dots 2 and 3. The right-hand index finger will use letter 'j' for dot 4, with 2nd and 3rd fingers of the right-hand using letters 'k' and 'l' for dots 5 and 6.

The 6 keys will be pressed in different combinations to produce the braille math codes required to complete all lessons in algebra. It is possible to press multiple keys at the same time. For example, to enter the cell dots 1 2 and 4 5 keys the f, d, j and k are to be pressed together.

'Enter' Key is used here to display message (or) display audio depends upon its function. i.e if error occurred, error message will be displayed and Narration/information will display for appropriate action.

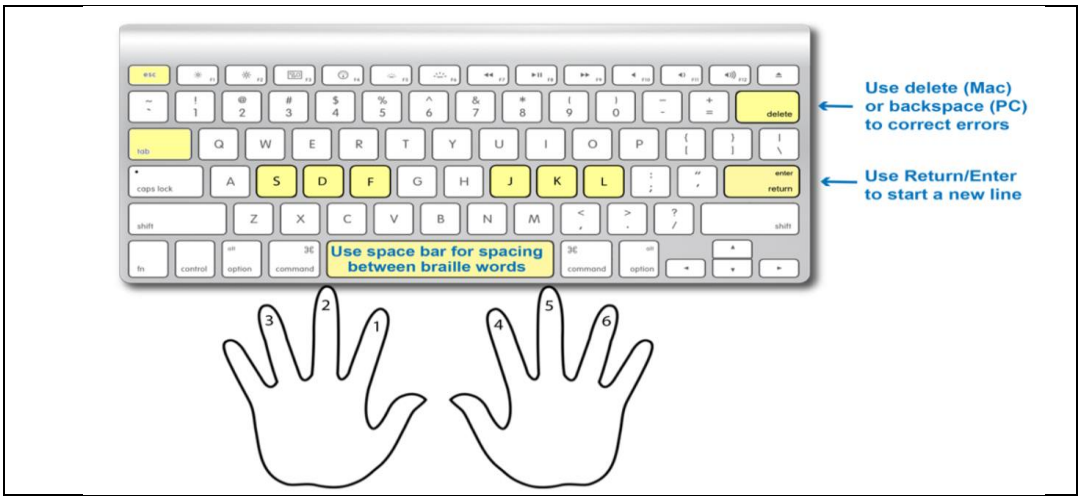

Figure: 3 Orientation Page

3. **Instruction for using the digital mode on learning of Algebraic Formulae**

Audio and Braille method was used to provide instruction and feedback of the results.

4. **Procedure for using digital mode on learning of Algebraic Formulae**

The students were asked to write the expression of the formula.

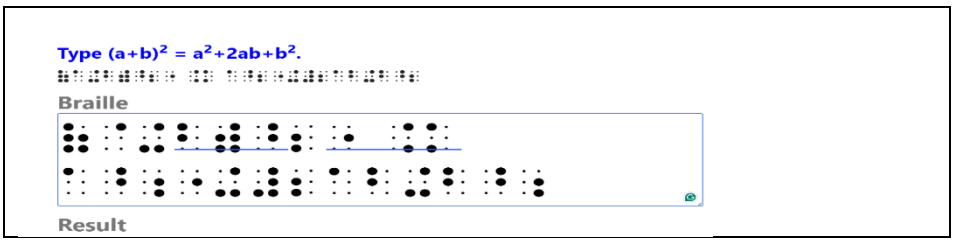

Figure: 4 An Example of Algebraic Formulae is given below as per screenshot:

The authors prepared the tool to assess all the algebraic formulae which cover from simple and complex formulae in digital form. The basic four identities and cubic identities formulae were assessed. The content selected for the study was from Samacheer Kalvi (Equitable Education) syllabus in Mathematics book from VIII Grade Math book in the State of Tamil Nadu. A total of seven formulae or Identities were selected for the study.

Analysis and Result

Analysis of Scores in Algebraic Formulae in different periods*:*

Sl No.	Test	No.	Mean	S.D
1.	Pre test	53	1.21	1.68
2.	Intermediate test	53	6.68	2.25
3.	Post test	53	10.91	3.43
4.	Delayed Post test	53	10.45	3.86

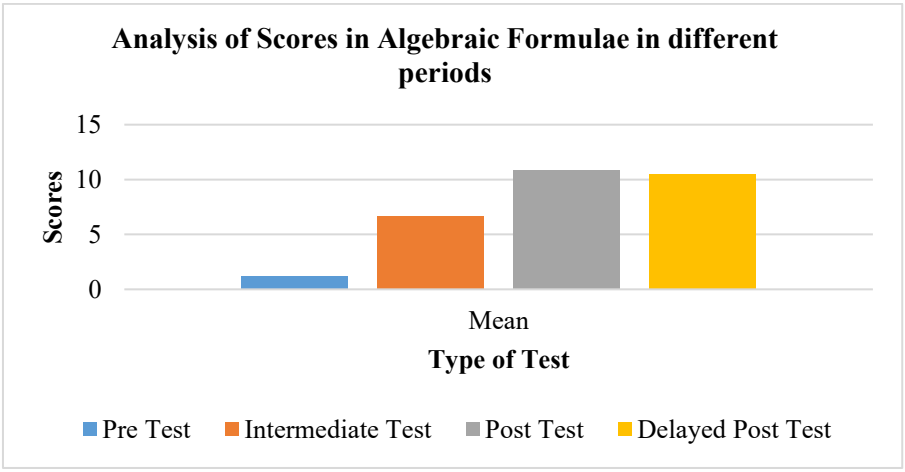

Figure: 5 Analysis of Score in Algebraic Formulae in different periods

Repeated Measures ANOVA Comparing Pre, Intermediate, Post and Delayed Post test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Interpretation
Between periods	3203.53	1.43	2237.89	427.72	.000	Significant difference between periods
Error	389.47	74.44	5.23			

[Sig 0.000 indicates significant at 1% level (P<0.01)]

The table shows the Algebraic Formulae ability scores and standard deviations (SD) for all the visually impaired students at four different tests: Pretest, Intermediate, Posttest, and Delayed Posttest. At pre-test, all the students scored low scores (Mean = 1.21). Over time, scores increased for all the students, showing improvement in learning Algebraic Formulae through the testing periods. At the intermediate test, they scored slightly higher (6.68) than the Pretest. At Posttest, they continued to have higher scores (10.91) compared to Intermediate test. At the Delayed Posttest, all the students still had higher than Pretest and Intermediate test but somewhat little lower scores compared with post score. The total means across all participants show a clear upward trend in scores, confirming overall learning or improvement in learning Algebraic Formulae over time. While all the students have numerically higher means at Intermediate, Post, and except in Delayed Posttests, these differences are significant at 0.01 level.

Repeated Measures for Pre, Intermediate, Post and Delayed Post Test with respect to Nature of Disability

		Overall Pre Test			Intermediate Test			Overall Post Test			Delayed Post Test		
		No.	**Mean**	**S.D**	**No.**	**Mean**	**S.D**	**No.**	**Mean**	**S.D**	**No.**	**Mean**	**S.D**
Nature of Disability	Totally Blind	25	1.36	1.80	25	6.56	2.20	25	10.72	3.16	25	10.16	3.60
	Low Vision	28	1.07	1.59	28	6.79	2.33	28	11.07	3.71	28	10.71	4.12
Total		53	1.21	1.68	53	6.68	2.25	53	10.91	3.43	53	10.45	3.86

The table shows the Algebraic Formulae ability scores and standard deviations (SD) for Totally Blind and Low Vision at four different times: Pretest, Intermediate, Posttest, and Delayed Posttest. At pre-test, both type of school such as Totally Blind and Low Vision had similar low scores (Totally Blind mean = 1.36, Low Vision mean = 1.07), indicating comparable starting ability. Over time, scores increased for both groups, showing improvement in learning Algebraic Formulae through the testing periods. At the intermediate test, Low Vision students scored slightly higher (6.79) than Totally Blind (6.56). At Posttest, Low Vision students continued to have higher scores (10.72) compared to Totally Blind (10.72). At the Delayed Posttest, Low Vision students still had somewhat higher scores (10.71) than Totally Blind students (10.16). The total means across all participants show a clear upward trend in scores, confirming overall learning or improvement in Algebraic Formulae over time. While Low Vision students have numerically higher means at Intermediate, Post, and Delayed Posttests, these differences are not significant. Hence, it is concluded that both Totally Blind and Low Vision students showed significant improvement between Pre and Posttest indicating the effect of Digital Mode on learning Algebraic Formulae. However, there is no significant difference between Totally Blind and Low Vision students in their score in all 4 periods.

Repeated Measures for Pre, Intermediate, Post and Delayed Post Test with respect to Type of School

		Overall Pre Test			Intermediate Test			Overall Post Test			Delayed Post Test		
		No.	**Mean**	**S.D**	**No.**	**Mean**	**S.D**	**No.**	**Mean**	**S.D**	**No.**	**Mean**	**S.D**
Type of School	Special School	39	1.08	1.44	39	7.03	2.05	39	11.38	3.08	39	11.03	3.43
	Inclusive School	14	1.57	2.24	14	5.71	2.58	14	9.57	4.09	14	8.86	4.62
Total		53	1.21	1.68	53	6.68	2.25	53	10.91	3.43	53	10.45	3.86

The table shows the Algebraic Formulae ability scores and standard deviations (SD) for special and inclusive schools at four different times: Pretest, Intermediate, Posttest, and Delayed Posttest. At Pretest, both type of school such as Special and Inclusive school had similar low scores (Special School mean = 1.08; Inclusive School mean = 1.57), indicating comparable starting ability. Over time, scores increased for both groups, showing improvement in learning Algebraic Formulae through the testing periods. At the intermediate test, Special Schools scored slightly higher (7.03) than Inclusive Schools (5.71). At Posttest, Special Schools continued to have higher scores (11.38) compared to Inclusive schools (9.57). At the Delayed Posttest, Special School still had somewhat higher scores (11.03) than Inclusive Schools (8.86). The total means across all participants show a clear upward trend in scores, confirming overall learning or improvement in Algebraic Formulae over time. While Special Schools have numerically higher means at Intermediate, Post, and Delayed Posttests, these differences are not significant. Hence, it is concluded that both Special and Inclusive schools showed significant improvement between Pre and Posttest indicating the effect of Digital Mode on learning Algebraic Formulae. However, there is no significant difference between Special and Inclusive schools in their score in all 4 periods.

Repeated Measures for Pre, Intermediate, Post and Delayed Post Test with respect to Gender

		Overall Pre Test			Intermediate Test			Overall Post Test			Delayed Post Test		
		No.	**Mean**	**S.D**	**No.**	**Mean**	**S.D**	**No.**	**Mean**	**S.D**	**No.**	**Mean**	**S.D**
Gender	Male	34	1.24	1.78	34	6.94	2.10	34	11.47	3.05	34	10.76	3.81
	Female	19	1.16	1.54	19	6.21	2.49	19	9.89	3.91	19	9.89	3.97
Total		53	1.21	1.68	1.68	6.68	2.25	10.91	10.91	3.43	53	10.45	3.86

The table shows the Algebraic Formulae ability scores and standard deviations (SD) for male and female at four different times: Pretest, Intermediate, Posttest, and Delayed Posttest. At Pretest, both Male and Female had similar low scores (Male mean = 1.24, Female mean = 1.16), indicating comparable starting ability. Over time,

scores increased for both groups, showing improvement in learning Algebraic Formulae through the testing periods. At the Intermediate test, Males scored slightly higher (6.94) than Female (6.21). At Posttest, Male continued to have higher scores (11.47) compared to Female (9.89). At the Delayed Posttest, Male still had somewhat higher scores (10.76) than Female (9.89). The total means across of all participants show a clear upward trend in scores, confirming overall learning or improvement in Algebraic Formulae over time. While Male have numerically higher means at Intermediate, Post, and Delayed Posttests, these differences are not significant. Hence, it is concluded that both Male and Female showed significant improvement between Pre and Posttest indicating the effect of Digital Mode on learning Algebraic Formulae. However, there is no significant difference between Male and Female in their score in all 4 periods.

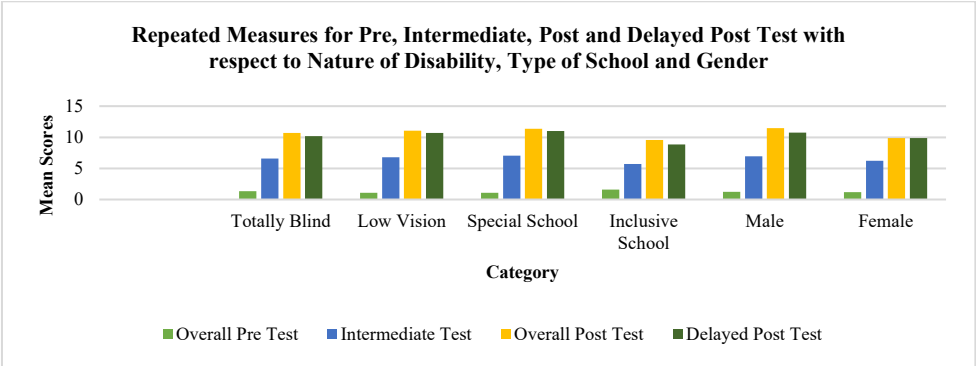

Figure: 6 Repeated Measures for Pre, Intermediate, Post and Delayed Post Test with respect to Nature of Disability, Type of School and Gender

RESULTS

The major findings emerged out of the study are given below with discussion:

Result 1: In the study, 53 students with visual impairment participated on analysing the data pertaining to the effect of Digital Mode on learning of Algebraic Formulae among these students, the result revealed that there is a significant effect of digital mode for learning. There is a consistent improvement on their learning when compared to Pre score (mean=1.21); Intermediate score (mean =6.68); Post score (mean = 10.91) and Delayed Post score (mean = 10.45). The result indicates that the Digital Mode designed and developed is efficacious on learning Algebraic Formulae among students with visual impairment.

Result 2: Analysis of scores of visually impaired students on learning Algebraic Formulae with respect to nature of visual impairment.

The nature of visual impairment viz. blind and low vision categories was considered. To find out if there is any difference between these two categories of students on learning Algebraic Formulae when the score were taken at different periods: Pre-test, Intermediate, Post and Delayed Post-test, the findings revealed that there is no difference between these two categories. However, the scores improved from Pretest to Posttest for blind. (Pre mean = 1.21; Post mean = 10.91), for Low Vision (Pre mean = 1.07; Post mean = 11.07)

Result 3: Analysis of scores of visually impaired students on learning Algebraic Formulae with respect to Type of School

When scores were analysed to find out the efficacy of Digital Mode on learning Algebraic Formulae with respect to Type of school viz. Special school for the Blind and the Inclusive School, the result revealed that there is a significant improvement from Pre-test (Special School mean = 1.08; Inclusive School mean = 1.57) to Posttest (Special School mean = 11.38; Inclusive School mean = 9.57). Therefore, it is concluded that the Digital mode benefits to students studying in Special School and Inclusive School. However, when compared the scores of students studying in two types of school, there is no significant difference between students of these two types of schools. It seems that the students of these two types of schools learnt the Algebraic Formulae to the same extent.

Result 4: Analysis of scores between Gender

The results indicate that there is significant improvement in the scores of both Male and Female when compared their scores from Pretest to Posttest. Male score: Pretest (mean = 1.24); Intermediate Test (mean = 6.94); Post Test (mean = 11.47); Delayed Posttest (Mean = 10.76). Female score: Pretest (Mean = 1.16); Intermediate Test (Mean = 6.21); Post Test (Mean = 9.89); Delayed Post-test (Mean = 9.89). While comparing the

scores secured between Male and Female, it was found that there is no significant difference between Male and Female on learning Algebraic Formulae using Digital Mode.

Result 5: Retention of learning Algebraic Formulae

When analysis was made with the help of Delayed Posttest to find out how the students retained the learning after the study period, the students showed retention of learning. The means scores are: Pretest (Mean = 1.21); Intermediate Test (Mean = 6.68); Post Test (Mean = 10.91); Delayed Posttest (Mean = 10.45)

DISCUSSION

Disability is no more a problem as there are many tools, teaching methods and design standards that make everything accessible to the disabled. The study results show that both Male and Female students improved in learning through digital mode when compared with Male and Female students in the usage of Digital Mode for learning. The present study states that there is different between Male and Female on learning Algebraic Formulae. The study conducted by Jackson et al (2001) showed a similar result that Male students slightly showed improvement in the Digital Mode than Female and Female are more nervousness in using computers and Male are more result oriented in using computers then Female.

The study on "Technology Acceptance Model" by Okazaki and Santos (2012), was found that there exists difference between Male and Female. Male are showing better attitude towards Technology Acceptance mode than female. Jones et al (2009) claimed that Male are frequent internet user than Female.

The present study findings report that Digital Mode benefits visually impaired students on learning Algebraic Formulae. This finding is concurrent with many studies conducted on use of Technology and Assistive Technology for the visually impaired. This finding is in line with study conducted by (Holzberger et al., 2013) that exhibited that Digital learning improves teaching effectiveness and enhances knowledge and skills. (Bouck et al., 2013) in their study on "etext Player ReadHear" present that students used technology to access Algebraic expressions.

Another interesting finding is that students with low vision slightly showed improvement when compared to blind students through Digital mode. This finding is in concurrence with these students. The findings show that Assistive Technology developed in the study which is Digital Mode for learning Algebraic Formulae has improved the learning among visually impaired students. Concerning the result of the study, it is noted that visually impaired students learn joyfully when ICT/Assistive Technology is provided with proper training. In this context, it is concluded that digital learning supported by auditory and tactile like Braille and Mathematical tools (Abacus/ Taylor Frame) can improve Math education for visually impaired students.

Institutional Review Board Statement: The Ethical Committee of the Avinashilingam Institute for Home Science and Higher Education Women, INDIA has granted approval for this study on 06.01.2023 (Ref. No. AUW/IHEC/EDU-22-
23/XMT-12).

Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.

Data Availability Statement: The data will be available on request

Competing Interests: We declare that we have no significant competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

Authors' Contributions: Participated in the methodology, Conceptualization, Data collection and writing the study; Author 2: Performed the Analysis the overall concept, writing and editing.

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