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COMPARATIVE STUDY ON SCREEN READER ACCESSIBILITY BETWEEN DIGITAL AND ACCESSIBLE MATHEMATICS TEXTBOOK

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INTRODUCTION:

The development of new learning technologies, recent advancements in Information and Communication Technologies (ICT), and digital resources have fostered self-directed learning among students. Mathematics has been recognized as a formidable roadblock for students with visual impairment. (A.P. Gulley et al, 2017).

Digital books designed to help users understand key conceptual structures of a book can enhance comprehension (Sun et al., 2004).

The National Federation of the Blind (NFB) claimed that many e-books do not meet the needs of the visually impaired. Equitable access to digital resources for the visually impaired is still limited and complicated (V. Bartalesi, and B. Leporini,2015)

Accessible textbooks are designed to enable students with visual impairments to learn as effectively as those using printed textbooks. Access to textbooks in accessible formats is a critical issue for visually impaired students. The UN Convention on the Rights of Persons with Disabilities (2006) recognizes access to information and communications technologies, including the Web, as a basic human right. Beyond web accessibility more than half of 'learning activities' in textbooks across subjects and grades are inaccessible for students with Visual Impairment.

The Rights of Persons with Disabilities Act, 2016 directs government authorities to provide "reasonable accommodation" to meet individual requirements of students under Section 16(iii), and in doing so "to make suitable modifications in the curriculum and examination system to meet the needs of students with disabilities", under Section 17(i). According to a recent study by the Vidhi Centre for Legal Policy (2021), all chapters sampled from NCERT e-textbooks were uploaded in an appropriate e-text format of which 36.4% were completely accessible. However, 54.5% had inaccessible elements, and 9.1%

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were completely inaccessible. Of the 21 SCERT chapters sampled for Tamil Nadu, 90.5% were totally inaccessible. Of the remaining chapters, 1 was partially inaccessible, including inaccessible elements such as tables and images without descriptions. Only one of the sampled chapters was totally accessible using a screen reader.

Hence this study aimed to analyze the 9th Grade Lessons in Digital Textbooks of Mathematics available in Tamil NaduTextbook website using screen readers such as JAWS, NVDA and NARRATOR. And Develop Accessible Textbook for the same Lessons in 9th Grade Digital Mathematics Textbook compare the accessibility of Digital and Accessible Text of the same lessons.

REVIEW OF LITERATURE

Sauer, L. (2020), stated that the ability to accurately read and subsequently comprehend a mathematical expression is vital to the understanding of mathematics.

Laisa Correa et al (2015) stated that, an educational and accessible digital book reader for mobile devices has been developed to complement digital accessible books.

Accessibility features help level the playing field for students with disabilities, allowing them to focus on learning, creating, and engaging with high-quality content.

To overcome limitations for those people who cannot meet their information needs from standard printed material, electronic documents can represent a very appropriate solution. In this direction several attempts have been made to develop specialised formats, especially for people with a visual impairment. One of these is a byproduct of the Daisy consortium, 2008 (Digital Accessible Information System), which is working on producing a standard for talking books characterized by navigational information to better move through the document (http://www.DAISY.org). As stated by Brzoza, P et al (2008), with this system, hybrid books can be made available in the DAISY format, ranging from audio-only, to full text and audio, to text-only. In November 2008, a new version of guidelines for DAISY standard 3.0 has been published. These Guidelines provide information on the correct usage and application of DAISY XML (the DTBookXML element set) in the creation of DAISY publications. Another major change in the DAISY 3 Structure Guidelines is the inclusion of information about NIMAS (National Instructional Materials Accessibility Standard) mark-up. NIMAS is the required electronic format in the U.S. for textbook publishers which produce K12 textbooks.

In India limited studies have involved in developing accessible textbooks using standard guidelines. In our study we prefer to propose solutions to design, develop or adapt accessible and usable e-books, which can be read with screen readers in order to obtain more general solutions, with the greatest benefits for all. In this sense, we consider solutions aimed at converting and adapting e-documents in order to make them more usable for visually impaired

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people.

METHODOLOGY

This study aims to develop accessible Mathematics Textbook and comparing its accessibility feature with Available Digital Mathematics textbooks. The study was conducted in two stages. Stage 1 was Developing Accessible Mathematics Textbooks for Students with Visual Impairment. The stage 1 comprised of three phases. In phase 1 the researcher analyzed the Accessibility of Available 9th Grade Mathematics Digital Textbook of Tamilnadu Government, India using "Accessibility Checker" and it was found that 32% of book only accessible.

During Phase two the available Mathematics Digital textbook was analysed for screen reader accessibility using different screen readers namely NVDA- Non-Visual Desktop Access, JAWS - Job Access with Speech and TALKBACK

In phase 3, the Mathematics Textbooks (Term 1) of 9th Grade has been developed as an accessible textbook. The "Microsoft Word 10" used to develop the books as accessible. Primarily Screen reader accessibility issues were considered and effort is taken to ensure the best possible overall user experience.

Six main accessibility Guidelines were followed to develop the accessible Mathematics textbooks. The first guideline was titles and subtitles were marked with the appropriate tags. Heading levels were selected according to the nature of the heading. Using proper 'Heading Levels' ensures better 'Navigation' within the Textbook. The second guideline followed was Paragraph and elements within paragraph (e.g. links, abbreviations and so on) were marked and tagged. It enhanced the possibility to easily search the content of e-book, take notes and create bookmarks. This also addressed the navigation issues and pause issues.

Next, Unordered and ordered lists were tagged to improve navigation between items and to better identify each list For example by using screen reader special command, the user is able to skip from one list to another.

Then Images were tagged and an appropriate textual description that clearly explains the information provided were given to each image.

And tables were also tagged and each table was given with an appropriate textual description that clearly explains the structure of table (e.g. Table has two columns) and the data contained in it (e.g. The first column contains users' names and the second one email)

Finally, Mathematics equations were created using Use Mathpix Snipping tool "Mathpix". This enhanced the accessibility of Math equations.

In stage 2 the newly developed accessible textbook and available Digital mathematics

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textbooks were compared on its accessible features.

In stage 2 a Comparative study was conducted to analyze the accessibility features of Tamil Nadu Government of 9th GradeDigital Mathematics Textbook and Newly Developed Accessible MathematicsTextbook.

A rating scale consists of 20 questions assess the Accessibility Features of the Textbooks using Screen Readers was developed. The Components included in the Rating Scale were i). Text, ii). Visual representation, iii). Content formatting, iv). Special characters, v). Accessible supports. Scoring key used was Completely Accessible - 3, partially accessible - 2, Inaccessible - 1

A sample comprised of 30 people with visual impairment were selected for the study. Purposive Sampling Technique was used to select the sample. Participants had a prior knowledge of using screen readers.

Participants involved in the study used different screen readers to read the mathematics textbook and gave their rating on accessibility Available Digital Mathematics textbook and Newly Developed accessible Textbook separately.

The participant's rating was compared the Overall Rating on Accessibility of Digital Textbook and Newly Developed Accessible Text Books for Mathematics using Screen Readers Namely JAWS, NVDA and TALKBACK.

And the participants rating was compared the accessibility with respect to Components namely i). Text, ii). Visual representation between Digital Text Book and Newly Developed Accessible Text Books for Mathematics using Screen Readers Namely JAWS, NVDA and TALKBACK.

RESULTS

Table 1. Comparison of Overall Accessibility of Digital Textbook and Accessible Textbook of Mathematics byStudents with Visual Impairment

Screen Reader	Book	Df	Mean	S.D	t-value
NVDA	DTB*	29	27.63	1.921	34.52**
	ATB*		48.57	2.285	
JAWS	DTB*	29	27.23	2.063	40.81**
	ATB*		48.63	1.956	
TALKBACK	DTB*	29	29.30	2.423	36.72**
	ATB*		48.60	1.850	

*** Significant at 0.01 level*

** DTB- Digital Textbook * ATB- Accessible Textbook*

From the table 1 it is evident that the t-value for Comparison on Overall Accessibility of Mathematics DigitalTextbook and Newly Developed Mathematics Accessible Textbook by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and

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TALKBACK are 34.52,40.81 and 36.72 with df = 29 which are significant at 0.01 level. It indicates that total tests score of Comparison on Overall Accessibility of Mathematics Digital Textbook and Newly Developed Mathematics Accessible Textbook by Students with Visual Impairment with Screen Readers differ significantly. In the light of the null hypothesis that there is no significant difference between the mean score of Comparison on Overall Accessibility of Mathematics Digital Textbook and Newly Developed Mathematics Accessible Textbook by Students with Visual Impairment with Screen Readers is rejected. Thus, the Students with Visual Impairment stated that the Newly Developed Mathematics Accessible Text Book has better accessible features than the Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

Table 2: Comparison on Visual Representation in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Students with Visual Impairment

Screen Reader	Book	Df	Mean	S.D	t-value
NVDA	DTB*	29	7.37	.964	25.51**
	ATB*		12.17	.986	
JAWS	DTB*	29	6.90	.923	19.19**
	ATB*		12.20	1.324	
TALKBACK	DTB*	29	7.63	1.245	13.27**
	ATB*		12.17	1.262	

*** Significant at 0.01 level*

** DTB- Digital Textbook * ATB- Accessible Textbook*

From the table 2, it is evident that the t-value for Comparison on Text Accessibility of Mathematics Digital Textbook and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 25.51, 19.19 and 13.27 with df = 29 which are significant at 0.01 level. It indicates that tests score of for Comparison on Text Accessibility of Mathematics Digital Textbook and Newly Developed Mathematics Accessible Textbook by Students with Visual Impairment with Screen Readers differ significantly. In the light of the null hypothesis that there is no significant difference between the mean score of for Comparison on Text Accessibility of Mathematics Digital Textbook and Newly Developed Mathematics Accessible Textbook by Students with Visual Impairment with Screen Readers is rejected. Thus, it is concluded that the students with visual impairment rated that the Newly Developed Mathematics Accessible Text Book has better Text accessibility features than the Mathematics Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

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Table 3: Comparison on Visual Representation in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Students with Visual Impairment

Screen Reader	Book	Df	Mean	S.D	t-value
NVDA	DTB*	29	6.47	1.137	18.09**
	ATB*		12.33	1.213	
JAWS	DTB*	29	6.60	1.276	20.72**
	ATB*		12.37	1.159	
TALKBACK	DTB*	29	7.20	1.270	19.61**
	ATB*		12.07	1.311	

*** Significant at 0.01 level*

** DTB- Digital Textbook * ATB- Accessible Textbook*

From the table 3, it is evident that the t-value for Comparison on Visual Representation in Mathematics Digital Textbook and Newly Developed Mathematics Accessible Textbook by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 18.09, 20.72 and 19.61 with df = 29 which are significant at 0.01 level. It indicates that tests score of Comparison on Visual Representation in Mathematics Digital Textbook and Newly Developed Mathematics Accessible Textbook by Students with Visual Impairment with Screen Readers differ significantly. In the light of the null hypothesis that there is no significant difference between the mean score of Comparison on Visual Representation in Mathematics Digital Textbook and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers is rejected. Thus, it is concluded that Newly Developed Mathematics Accessible Text Book has better accessible features in Text Accessibility than the Mathematics Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

DISCUSSION

The researchers suggested methodologies for providing visually impaired students with complete accessibility to the curriculum.

The Overall Accessibility Features rated by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK showed that the Newly Developed Mathematics Accessible Text Book has better overall accessibility features than the Digital Mathematics Text Book (Digital Mean: 48.57, 48.63, 48.60 & Accessible Mean: 27.63, 27.23, 29.30). This result coincides with the result

Pertaining to the results of Students with Visual Impairment the Newly Developed Accessible Mathematics Text-book has better in all accessibility components than Digital Mathematics Textbook with Screen Readers namely NVDA, JAWS and TALKBACK. I) Text: Accessible Mean: 12.17, 12.20, 12.17 & Digital Mean: 7.07, 7.27, 7.47.ii) Visual Representation: Accessible Mean: 12.33, 12.37, 12.07 & Digital Mean: 6.47, 6.60, 7.20.

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According to American Foundation for the Blind, AFB, (2017). PDF files can be problematic for individuals with visual impairments. Blind students may encounter PDFs that are poorly formatted, resulting in text appearing misaligned, columns running together, or captions inserted inappropriately. Additionally, hyperlinks to other sections or online resources might be confusing. Often, PDFs are not optimized for screen readers, and some files may contain images of text rather than the actual text. In such cases, Optical Character Recognition (OCR) software may be necessary to convert these images into text that can be read by screen readers. Modern OCR software, whether designed for accessibility or general use, increasingly delivers high-quality text extraction from images. Publishers need to provide books in accessible formats compatible with screen reader software, and addressing this issue can require time and persistence. This study paves ways to rectify challenges in developing accessible materials for the visually impaired.

CONCLUSION

Textbook inaccessibility is the hardest barrier for students with visual impairment in their education. With the advancement in computer technology, textbooks can be being prepared and produced using computers in accessible formats. Thus, the new possibility opens for students with visual impairment. The readily available electronic files of the textbooks can be read with screen readers. Accessible Textbooks brings a significant advancement in favour of people who are Visually Impaired or have a print disability. The standard and the new technology provide a better reading experience and have the potential to encourage both visually impaired students to get equity in access to materials on par with sighted peers.

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