

**DEVELOPING ACCESSIBLE TEXT BOOKS FOR  
STUDENTS WITH VISUAL IMPAIRMENT**

*Submitted by*  
**SHOBANA R**  
**(Reg.No.20PSE004)**

*Under the guidance of*  
**Dr. M. REVATHI, M.Sc., M.Ed(VI),Ph.D., NET**  
**Assistant Professor**  
**Department of Special Education**

**A THESIS SUBMITTED TO THE  
AVINASHILINGAM INSTITUTE FOR HOME SCIENCE AND  
HIGHER EDUCATION FOR WOMEN  
COIMBATORE - 641 043**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE  
DEGREE OF MASTER OF EDUCATION SPECIAL EDUCATION  
(HEARING IMPAIRMENT)**

**May 2022**

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**CERTIFIED AS A BONAFIDE RESEARCH WORK**

**Signature of the  
Head of the Department**

**Signature of the  
Dean of the Faculty**

**Signature of the  
Guide**

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# CHAPTER I

## INTRODUCTION

*“Accessibility ensures people with disabilities can access the same information from a system as everyone else, and also gain the same benefits”*

### 1.0. Introduction

The present study entitled **“Developing Accessible Text Books for Students with Visual Impairment”** is related to development of Accessible Textbooks for Science and Mathematics Subjects of TamilNadu State Board Curriculum. The present study consists of two stages. Stage 1, aimed to develop accessible text books with enhanced accessibility features in digital text books for effective use of the students with visual impairment with screen readers. In stage 2, Comparison study was conducted between the digital and Accessible text books on the enhanced accessibility features for screen reader usage.

In this chapter, the detail in respect to; Education of Children with Visual Impairment, Concept of Accessibility, E-Text Book for Visual Impairment, Accessible Digital Text Book, Benefits of Accessible Digital Text Book in Learning, Advantages of Accessible Text Books for Different Disabilities, Challenges of using the Accessible Digital Text Book, Availability of Digital Text Book for Students with Visual Impairment, Objective of the Study, Hypothesis of the Study, Scope of the Study, Limitation of the Study, Organization of the Study were discussed.

#### 1.1.0. Education of Children with Visual Impairment

The visually impaired people have the same information needs as sighted people, and that it is mainly the need for alternative formats that is specific for visually impaired users. However, an underlying problem regarding social inclusion seems to be implied in discussion (Adetoro’s, 2010).

The Schools are now required to place disabled students in inclusive classrooms, so need for technology increased, in order to provide them with the social skills and academic tools as the other students. In the same way, distance learning is an increasingly popular way for institutions of higher learning to deliver educational services to students. It is popular among disabled students as well (Edmonds, 2004).

Thus, electronic material, such as e-books or e-texts, is increasingly used as a learning tool.

Students with visual impairment rely on alternative-format books such as large or Braille print or audio versions. Unfortunately, the time-consuming process of turning books or other materials into Braille, audiotape, or large-print editions makes the visually impaired students often start the school year without their textbooks. Thus, while the other students receive complete printed books, vision-impaired students receive their study material chapter by chapter with the risk that it does not arrive in time for them to continue with the learning schedule. (Leporini, B.2009).

### **1.1.1. Benefits of Digital Technology in Learning**

Technology tools have become deeply entwined in the ways that we learn, work, communicate, play, and shop (Crosland et al., 2016). Instructional technologies play an important role in creating universally designed learning environments.

Edyburn (2010) highlights the key role of technology in the provision of universally designed environments, as a tool that can increase accessibility and engagement. Digital text inherently provides options where text can be converted easily to audio; can be displayed in different fonts, colours, and layouts on the screen; can be simplified as needed; and can be translated into other languages. This inherent flexibility allows digital text to be accessible to students with vision impairments, students with learning disabilities, students learning the language of instruction, and others who would simply prefer to modify or access text to suit their preferences.

Hughes and Talbott (2017), postulates that instructional technologies can provide flexible options for learning in a variety of way swallowing students to view information represented in various ways, express themselves creatively, and to engage in authentic and meaningful forms. For example, online environments can be designed with varied options built into the technology, allowing users to choose from a variety of supports such as text -to-speech, online glossaries, hyperlinks to related information and tools for note-taking and comprehension (e.g., highlighting tools).

Technology can also provide means for students to express information in various creative formats, and consequently serve as non-traditional means of

assessment. For example, instead of a written assessment to gauge a student's knowledge, students can use multimodal tools available on computers and mobile devices to express information orally or visually (e.g., audio or video recordings). These options can be useful for learners who benefit from having alternatives to written expression of knowledge.

Technology can support much of the effort toward curriculum access, participation and progress. Technology increases independence, personal productivity and empowerment. It can facilitate the kinds of interactions that occasion instruction, and it can transform static curriculum resources into flexible digital media and tools (Jackson, 2004; Stahl, 2004).

### **1.1.2. Concept of Accessibility**

Accessibility is a critical key to leverage the power of technology and provide equal educational opportunity for all students, particularly those with disabilities. This concept involves the design of materials such as curricula and resources, devices such as smart phones and tablets, digital tools such as computers, apps, and games, and platforms such as online learning and website that support access to educational content and activities (Crossland, Gray, Reynolds, Wellington & Zhou, 2016). Furthermore, accessibility refers to accommodating individual cognitive and physical needs to remove unnecessary obstacles so that students can demonstrate their knowledge and skills in formative and summative assessments.

### **1.1.3. Accessible Digital Textbook**

The definition of “accessible format copy” is fairly broad and covers any format that permits a person with a visual impairment or other print disability to have access to the content as feasibly and comfortably as a person without such a disability, including digital formats (World Intellectual Property Organization (WIPO),2017).

According to Curry, Carl, & Pérez (2018), accessibility referred as “when a person with a disability is afforded the opportunity to acquire the same information, engage in the same interactions, and enjoy the same services as a person without a disability in an equally integrated and equally effective manner, with substantially equivalent ease of use. It guarantees a student with a disability is provided with

curricular materials in needed formats, and technologies with required features, in a timely manner.

Accessible materials are aimed at ensuring that people with disabilities can navigate, perceive, and understand content that takes into account the physical, visual, speech, auditory, neurological, and cognitive disabilities of the user (Gray & Blackorby, 2017).

Accessible digital materials should adhere to the principles of Universal Design for Learning (UDL). There is a growing awareness of the supports necessary to ensure accessible learning can be built into the hardware and software at the inception of the development process. This approach is referred to as “born accessible” or universal design for learning (UDL) (Crosland et al., 2016).

The UDL guidelines offer a set of concrete suggestions that can be applied to any discipline or domain to ensure that all learners can access and participate in meaningful, challenging learning opportunities (CAST, 2018). In curricula developed with the UDL Guidelines, materials provide multiple means of engagement; representation; and action and expression. In addition to materials, the UDL framework guides the design of instructional goals, assessments, and methods that can be customized and adjusted to meet individual needs.

#### **1.1.4. E-Text Book for Visual Impairment**

Use the term e-document for contents (text, figures etc.) that is stored in electronic format. Thus, an e-document can be a simple text, a more complex document, with title, paragraphs and subparagraphs, or an electronic book organized into chapters and sections.

The accessible textbook will help the students to learn like normal students in a printed textbook. Access to textbooks in accessible format is one of the important barriers of students with visual impairment in their education. (Sirirungruang, 2011). With the advancement in computer technology, textbooks are now being prepared and produced using computers. (Dakin and Wijesena, 2005) Thus, the new possibility opens up for students with visual impairment. The ready available electronic files of the textbooks means that the reproduction of these textbooks into alternative formats

that are accessible to students with visual impairment can be done with less time (Dakin and Wijesena, 2005; Roos, 2007) and less cost (Harpur and Suzor, 2013).

To develop technical and methodological solutions need to be used to overcome the main barriers to create e-documents that can be accessed and useable by disabled users. E-Text books analyses will relate to e-book user experience by considering both end users i.e. blind students and adapting-center operators (Calabrò, A., Contini, E., 2009).

E-Book browsers that aid users in perceiving and understanding the important conceptual structures of a book, and hence improve their comprehension of the book content (Sun et al., 2004).

A new generation of e-books, redesigned an e-book in the area of law. An evolving e-book prototype have been developed which allowed them to examine the interconnected issues of usability and utility, and to redesign an existing e-book user interface to suit the needs of law students. The authors considered facilities, such as text navigation, reading, annotation, following links. (Marshal et al., 2001)

An educational and accessible digital book reader in mobile devices was developed, aiming to complement digital accessible books for education. The work presents a digital book with support for knowledge assessing, text reading, worksheets, drawing and tactile images and maps. ( Laisa. Corrêa, Ana Grasielle. Dalmon, Danilo, 2015)

Considering the graphical nature of the web, the access, navigation and interpretation is highly difficult for people with visual impairment or blindness. Commonly, they use screen readers to access web pages, which outputs the content to a braille display or to voice output. Also, users with visual impairment or blindness typically use their keyboard to navigate, tabling through content and pages and use features like magnifier or high contrast if available (McLaughlin & Kamei-Hannan., 2018).

### **1.1.5. Advantages of Accessible Textbooks for Different Disabilities**

Stahl (2004) and Crosland et al., (2016) outlines the benefits of accessible digital textbook as follows:

1. Improves student learning -Accessibility features can help place your students with disabilities on an equal footing with their peers and focus their energies on learning, creating, and engaging with high-quality content. For learners with visual impairment and low vision the accessible digital textbook would increase the quality of braille-compliant digital files and significantly accelerate the delivery of alternate format materials to students with visual impairments.
2. For students with physical disabilities, a more unified approach will allow for the creation of varied, well-structured and complete student-ready versions, including easily navigable digital files with images, from the same source file, eliminating redundancies and simultaneously improving the accuracy of the alternate version and aligning it with the print work. There are a number of physical disabilities that can also be aided through digital innovations for those with motor and coordination disabilities who have trouble turning a page or holding a book. A basic e-reader or phone with touch screen technology can be used to turn a page with a simple touch.
3. For students with learning disabilities, the availability of textbooks in accessible alternative formats suitable for representation via human or synthetic speech would significantly increase the independent use of these core curriculum resources by students with learning disabilities. In addition, captions improve literacy for struggling readers and promote comprehension and language development for struggling readers by reading the words on the screen and hearing the words spoken aloud.
4. For students who are Deaf or hard of hearing. The increased availability of digitally-based standard textbooks provides the necessary foundation elements for the subsequent creation of learning resources that contain both signed and text versions of the same instructional content. In addition, captioning not only supports people with hearing disabilities, but also enhances the user experience for all users. In conclusion, accessible, flexible alternate versions of core curriculum materials can increase engagement, attention and

achievement by offering adjustable levels of complexity, novelty and mixed media.

### **1.1.6. Challenges of Using the Accessible Digital Textbook**

Inaccessible materials is one of the barriers to attending school for children with disability and if they cannot participate fully in the classroom they will be less motivated to attend (UNICEF,2014) For effective utilization of the accessible digital textbook teacher capacity is critical. According to Hughes & Talbott (2017), one of the challenges is that teachers are untrained, unwilling, or unavailable. Many teachers cannot forfeit traditional pedagogical cultures: inflexible age-graded curricula and assessment frameworks to cater for diversity.

Many teachers do not cater to the needs of those with disabilities and demand that they perform as regular students; at other times, they are taught a remedial curriculum or not taught at all (Human Rights Watch, 2013).

The accessibility is determined by the user, as opposed to being one fixed set of formats or features. The functional skills required for using digital materials and technologies, including physical, sensory, and cognitive, vary widely within and across learners.

According to CAST, 2018 & Gray& Blackorby, 2017, Learners require digital materials according to their disability as follows:

1. Learners with auditory disability that is ,heard of hearing and deafness may not use audio content that lack captions and transcripts
2. A student with low vision may need a high contrast white on black screen display but the same high contrast display could make reading more difficult for someone with a reading difficulty such as dyslexia.
3. A student may proficiently navigate a tablet screen using finger swipes, pinches, and taps, while a student with motor challenges may need to use switch technology to access the same device.
4. A student with a writing challenge such as dysgraphia needs speech recognition to write an essay, while another student with a learning disability uses text to speech to hear the essay read aloud while drafting it.

5. With the increasing prevalence of digital learning materials and the integration of computers in all facets of education, it is important that these materials be made accessible to populations with disabilities. These digital resources can be more convenient to retrieve and manipulate (e.g., change font size or color) than their physical, printed counterparts, making them more accessible to people with disabilities, especially those with visual impairments. In light of the potential impact that accessible materials could have on student learning, standardized techniques for developing accessible materials and evaluating accessibility are presently unavailable.

### **1.1.7. Availability of Digital Textbook for Students with Visual Impairment**

The state textbook adoption program that shifted from sole reliance on traditional, print-based textbooks to a wide variety of instructional media. These recently available formats include, but are not limited to computer software, compact disks (CD-ROM), videotapes, interactive videodiscs, and instructional materials downloaded from the Internet or the various online services. The traditional textbooks were produced in braille, large print, or audiotapes to be accessible to students who are blind or visually impaired. However, the latest instructional media formats cannot easily be made accessible to students with disabilities.

Bookshare is a free service for students in K-12 and college institutions that allows them to receive books in a print disability friendly format such as ePub, audio, Braille, and more. Bookshare has over half of a million different titles and quite a few textbooks, so users can download up to 50 titles a month at no cost. I used Bookshare to download required readings for my English class and was super excited to have everything in an easy-to-access format.

The text from hard copy where it is difficult or impossible to read with low vision onto video screens where it can be manipulated visually, and then into digital representations which can be customized. Digital documents on computers and mobile devices permit easy manipulation of print size, contrast polarity, font, color, and layout. High-tech digital image enhancement methods for low vision are also under study (Moshtael et al., 2015)

Digital documents on computers and mobile devices allow customization of print size, spacing, font style, distinction polarity and page layout to optimize reading displays for individuals with low vision. As a result, the researcher tends to currently have opportunities to adapt text format to fulfill the wants of visually impaired readers. Text variables on low-vision reading: Print size and show size matter, Magnification is typically necessary, High distinction is commonly essential, Bright displays and distinction reversal are fascinating, Inter-line and inter-word spacing might facilitate, Font effects are tiny; however fastened dimension fonts could also be useful once reading close to the acuity limit. (Legge, G. E., 2016).

### **1.1.8. Accessible Textbooks in PDF Format**

PDF files can be challenging for people with visual impairment. The blind student will receive PDF files that have been marked up in such a way that text does not appear out of place columns being run together, or picture captions inserted in odd places and material hyperlinked to other parts of the text, or the Internet. Often, however, PDF files will not be properly formatted for the best reading experience with a screen reader. Sometimes, a PDF file will contain an image of the text in a book, but not the actual text itself. In this case, OCR (optical character recognition) software may be required to convert the image in the PDF file into text that can be read by a screen reader. Today's OCR software, whether specialized for the blind or mainstream, is increasingly able to produce quality results from an image such as that found in a PDF file. Publishers have to offer their books in a format that must be read by software. This software is often not accessible to screen readers, and the publishers must be made to understand the problem. This sometimes takes time and patience (American foundation for the blind AFB, 2017)

### **1.1.9. Challenges in Creating Accessible Books**

Nowadays, a serious problem is the slow and expensive production of e-books that are both accessible and for all, including people who have to interact with assistive technologies (e.g. a screen reader). To obtain a concrete accessible and usable e-book, the contents and the structure have to conform to appropriate procedure and rules. The e-book content is adapted by a person - called an operator -.

Carrying out those actions manually is time-consuming and requires a lot of actions by the operators.

Lack of access to quality education continues to be one of the largest challenges for children with disabilities. In accessible education facilities, inflexible curricula, the lack of assistive devices, inaccessible learning materials and teachers who are not yet prepared to support diverse learning needs in the classroom can all serve as barriers to the education of students with disabilities (Hayes, Turnbull and Moran, 2018).

The main reasons for this limitation can be summarized as follows:

- Lack of clear guidelines that help authors/publishers to build a really accessible and usable e-book;
- Lack of tools able to support the entire conversion process;
- Lack of a standard intermediate format that makes it possible abstract data book content and that is not limited to final distribution formats such as PDF, XHTML, HTML5, DAISY 3.0 and Braille;
- Lack of consideration by publishers of blind and visually impaired student needs
- Lack of screen-readable text books has been one of the most challenging problems for visually impaired students. The visually impaired students use text-to-speech software like JAWS for reading books on his computer.
- For the visually impaired students provide some of books in PDF format but even these books were not navigable by the screen reader software. And most of the reference books were not even available in e-book format. To take this challenge, converted the required text books into screen-readable and navigable MS Word format.

#### **1.1.10. Challenges in Digital Learning Opportunities**

The development towards the increased use of digital learning opportunities is challenging for students with visual impairments (VI) and their teachers (Asebriy et al., 2018; Ashraf, Hasan, Lewis, Hasan, & Ray, 2016). Therefore, it is relevant to gain more knowledge about how students with vision loss can follow the teaching in

mathematics and succeed in learning their age-related curricula (Besnoy, Manning, & Karnes, 2005; Ferrell, 2011; Klingenberg, 2013).

All students should have the opportunity to obtain an age-related level of competence in mathematics according to their abilities. However, students with Visual Impairment face greater challenges in learning from digital libraries and the web (Ajuwon, Meeks, Griffin-Shirley, & Okungu, 2016; Asebriy et al., 2018). Moreover, their visual disability may mask their actual mathematical abilities, creative thinking, and academic achievement potential (Al-Dababneh, al-Masa'deh, & Oliemat, 2015). Therefore, teaching strategies and aids is an important component of the learning environment (Hassan & Salleh, 2017).

Gaps in digital skills may increase among students with VI compared with students without vision loss (Ramos & de Andrade, 2016), and one reason may be the fast development in digital- based learning. Another reason may be the lack of sufficient resources and adequate aids

#### **1.1.11. Use of Screen Readers for Accessibility**

Many developments occurred in the internet and computer technology fields addressing to the disabled individuals recently. Especially, the letters on the screen may be read through the adapted technologies such as speech synthesizing or Braille visions (Suba `Flu,2010).

Technology in many software packages, including many word processing software and educational software programs, the users can adjust the volume, pitch, speed of reading; can be easily operated by keyboard commands. It makes use of a synthetic voice output system and the user can select whether they want a male or a female voice, some screen readers also make use of digital speech i.e. the actual recordings of human voice. It is much easier to understand but has the disadvantage that it requires huge storage space as each word that the computer may come across is pre-recorded for the benefit of the user, hence it is not very feasible (Ramakrishna, 2011).

A screen reader takes the standard output from a computing or mobile device and presents it to a user in either an audio or tactile output such as a Braille display.

The audio output mechanism - the text-to-speech (TTS) engine, which is the primary output for a majority of people with vision impairments. The TTS refers to the speech synthesis, which artificially produces human speech through one of various means featuring methods such as the concatenation of human speech samples or machine generated synthetic sounds. Based on factors such as the language spoken and the phonetic construction of words, the amount of complexity in the overall voice output mechanism can vary dramatically. The TTS is generally independent of the screen reader, and building a high quality TTS can be a fairly effort-intensive project. The reason a discussion of the TTS is central to any conversation on screen reading preferences is because the aesthetic quality of a user's experience with a screen reader and the intelligibility of the output is fundamentally tied to the speech engine. Several of the major screen reading products come with a bundled synthesizer or have an exclusive arrangement with one or another TTS manufacturer.

Without access to screen readers, independent access to computing and office applications, web use, and even communications can be severely limited, and these are consequently critical to the workplace and social environment of people with vision impairments.

Screen reading software converts the text that appears on the computer screen into speech, which enables people with visual impairments to access the content. This software facilitates their education and provides various employment opportunities in computer-oriented jobs. JAWS (Job Access with Speech), NVDA (Non Visual Desktop Access), Orca and Narrator are universally used screen reading software. Apart from these, screen reading software such as Talks, eSpeak, Google text-to-speech, Shine Plus, VoiceOver and TalkBack are used on mobile-based platforms.

NVDA (Non Visual Desktop Access) It is screen reader software (open ware or free ware) that works on the TTS (text-to-speech) engine which helps to convert the text into speech, enables blind and visually impaired users to use the computer. It makes use of a synthetic voice output system and has proved to be very useful for learners with visual impairment and even to learners with learning disability.

JAWS is a powerful screen reading application with many useful features that provide access to a wealth of information across multiple platforms. Whether you use

it to navigate screen content or are teaching others to do so, there are several distinct advantages to knowing its various keystrokes and capabilities.

JAWS includes a vast array of keyboard commands and features designed to provide speech and Braille output to users who are unable to see screen content or navigate using a mouse. This makes performing both simple and more complex tasks possible, adding greater functionality to the user experience.

TalkBack is an Accessibility Service for Android which helps blind and vision-impaired users interact with their devices more easily. This screen reader software adds spoken, audible and vibration feedback to your device. TalkBack provides spoken feedback as you navigate around the screen, by describing your actions and informing you of any notifications. It is a system application and comes pre-installed on most Android devices. The application is updated when the Accessibility Service is improved.

## **1.2 Statement of the Problem**

The statement of the study was “**Developing Accessible Text Books for Students with Visual Impairment**” The main focus of the study was to developing accessible textbook for students with visual impairment by analyzing the level of accessibility in digital text book by using screen readers.

## **1.3 Rationale of the Study**

Accessibility in general means the extent to which the complete use of any resource is available to the greatest number of people (Booth, 2012). Accessibility involves two issues: whether users with disabilities can access electronic information and how document content functions with assistive technologies (Adobe, 2016).

“The UN Convention on the Rights of Persons with Disabilities recognizes access to information and communications technologies, including the Web, as a basic human right” (W3C, 2010, Why: The Case for Web Accessibility section, para. 1). It is important that websites and documents provide equal access and opportunities to everyone, including people with diverse abilities.

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).

The RPWD Act 2016 puts the onus of accessibility of educational resources for students with disabilities, including students with visual disabilities, solely on the state as providers of education. Yet this study finds that much of the learning materials hosted on the Centre’s DIKSHA platform are not accessible to students with visual disabilities and the platform itself is not navigable with the use of a screen reader.

According to a recent study by the Vidhi Centre for Legal Policy, more than half of the NCERT textbooks available on the government’s virtual education platform DIKSHA are not accessible for visually impaired students. In fact, the DIKSHA platform itself is difficult to navigate for visually impaired students, said the report.

The mobile application of the DISKHA platform had only a few elements, such as QR codes, that could not be used independently by a student with visual disability. However, the mobile application is only available for android devices, despite IOS being more accessible for persons with visual disability. Additionally, it is key to note while the mobile application is far more accessible than the web platform, students with visual disabilities prefer to still use computers as they find it easier to navigate reading materials with the use of a keyboard due to the various shortcuts and other capabilities screen reading softwares provide when using a keyboard.

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% 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.

Of the 22 SCERT chapters sampled for Telangana, none were totally inaccessible, however 95.5% were partially inaccessible, and only one chapter was totally accessible.

Text book is extremely important materials for education purpose for the students; nowadays technology plays an important role in education system. The Digital Text Books are available in PDF formats and those are not in an accessible format for the students with visual impairment; for example the image and diagram description is not clearly mentioned, QR link is not clearly mentioned, the order of reading is sometimes varies, skipping some line in while reading and so on. By analyzing the digital text book by using the screen reader the result shows that the digital book is lower in accessibility level. So the visual impairment students can't able to get proper accessible materials.

Hence this study aimed to analyze the 8<sup>th</sup> Grade Lessons in Digital Text books of Science and Mathematics Subjects available in Tamilnadu Text Books website using screen readers such as JAWS, NVDA and NARRATOR. And Develop Accessible Text Books for the same Lessons in 8<sup>th</sup> Grade Digital Text books of Science and Mathematics Subjects and compare the accessibility of Digital and Accessible Text of the same lessons.

#### **1.4 Objective of the Study**

The major objectives of the study were to

1. Analyze the Accessibility in Digital Text book of Science subject available in Tamilnadu Government Text Books using screen readers namely JAWS, NVDA and TALKBACK.
2. Analyze the Accessibility in Digital Text book of Mathematic Subject available in Tamilnadu Government Text Books using screen readers namely JAWS, NVDA and TALKBACK.

3. Develop an Accessible Science Text Book for Students with Visual Impairment.
4. Develop an Accessible Mathematics Text Book for students with Visual Impairment.
5. Compare the Accessibility of Digital Books and Newly Developed Accessible Text Book of Science Subject Screen Readers such as JAWS, NVDA and TALKBACK.
6. Compare the Accessibility of Digital Text Book and Newly Developed Accessible Text Book of Mathematics using Screen Readers such as JAWS, NVDA and TALKBACK.
7. Compare the Accessibility of Digital Text Book and Newly Developed Accessible Text Book for Science with respect Text, Visual representation, Content formatting, Special characters, Accessible support for Accessibility using Screen readers such as JAWS, NVDA and TALKBACK.
8. Compare the Accessibility of Digital Text Book and Newly Developed Accessible Text Book for Mathematics with respect to Text, Visual representation, Content formatting, Special characters, Accessible support for Accessibility using Screen readers such as JAWS, NVDA and TALKBACK.

### **1.5 Hypothesis of the Study**

1. There is no significant difference between the mean score of Comparison between Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment using Screen Readers.
2. There is no significant difference between the mean score of Comparison between Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with respect to Screen Readers
3. There is no significant difference between the mean score of Comparison between Science Digital Text Book and Newly Developed Science Accessible Text Book with respect to variables namely i) Text, ii) visual representation, iii) content formatting, iv) special characters, v) accessible support by Students with Visual Impairment with respect to Screen Readers.

4. There is no significant difference between the mean score of Comparison between Mathematics Digital Text Book and Mathematics Accessible Text Book by Students with Visual Impairment with respect to Screen Readers
5. There is no significant difference between the mean score of Comparison between Mathematics Digital Text Book and Mathematics Accessible Text Book by Special Educators with respect to Screen Readers.
6. There is no significant difference between the mean score of Comparison between Mathematics Digital Text Book and Newly Developed Mathematis Accessible Text Book with respect to variables namely i) Text, ii) visual representation, iii) content formatting, iv) special characters, v) accessible support by Students with Visual Impairment with respect to Screen Readers.

### **1.6 Scope of the Study**

1. The present study will enable the Students With Visual Impairment to easily access the digital text book
2. The Teachers of Visual Impairment students can make use of this digital text book to teach Visual Impairment students.
3. This study may provide more equity to Students with Visual Impairment in access to the Text Books.
4. This study would suggest the ways to develop accessible materials for Students with Visual Impairment with easily available techniques and technology.

### **1.7 Limitation of the Study**

The limitations of the study are listed below:

1. The study focused only the accessibility need of Students Visual Impairment
2. The study assessed and developed text book with screen reader accessibility, other kinds of accessibility colour contrast, magnification were not considered.
3. The study used only three screen readers namely JAWS, NVDA and TalkBack
4. The study developed accessible text books for Science and Mathematics subject only.

## **1.8 Organization of the Study**

The study on “Developing Accessible Text Books for students with Visual Impairment” is reported in five chapters.

- CHAPTER I** : Chapter includes the Introduction.
- CHAPTER II** : The second chapter presents the Review of Literature related to the topic.
- CHAPTER III** : The third chapter explains the procedure, methods adopted in the study, construction of tools, selection of samples, administration of the tools and Data collection procedure.
- CHAPTER IV** : The fourth chapter deals with the tabulation, analysis and interpretation of the data in detail.
- CHAPTER V** : The fifth chapter reports the findings, recommendations and suggestions.

This is followed by bibliography and appendices.

The review of related literature is presented in the next chapter.

## CHAPTER II

### REVIEW OF LITERATURE

#### **2.0. Introduction**

A literature review surveys books, scholarly articles, and any other sources relevant to a particular issue, area of research, or theory, and by so doing, provides a description, summary, and critical evaluation of these works in relation to the research problem being investigated. Literature reviews are designed to provide an overview of sources you have explored while researching a particular topic and to demonstrate to your readers how your research fits within a larger field of study (Fink, Arlene. 2014)

A literature review is a survey of scholarly sources on a specific topic. It provides an overview of current knowledge, allowing you to identify relevant theories, methods, and gaps in the existing research (Shona McCombes., 2022).

In the first chapter, Rationale along with Objectives and Hypotheses has been given. The present chapter is devoted to reviewing researches related to various aspects of Accessible Text Books for students with visual impairment. The researches have been classified for better understanding mentioned as follows.

The related review studied has been structured under the following headings:

- 2.1. Digital versus Traditional Text Books for Visually Impaired
- 2.2. Audio Books for students with Visual Impairment
- 2.3. DAISY Talking Books for Visually Impaired
- 2.4. E- Book Accessibility Standards
- 2.5. Accessibility Evaluation of E-Text Books
- 2.6. Development of Accessible Books
- 2.7. Impact of Digital Talking Books on Education of Students with Visual Impairment
- 2.8. Developing the Accessible Mathematics Content for Visually Impairment Students
- 2.9. Technology Aided Reading for Visually Impaired
- 2.10 Digital versus Traditional Text Books for Visually Impaired
- 2.11 Audio Books for students with Visual Impairment

## **2.1. Digital versus Traditional Text Books for Visually Impaired**

**Emily C. Bouck, Pei-Lin Weng, and Rajiv Satsangi (2016)** conducted a research on **“Digital versus Traditional: Secondary Students with Visual Impairments”** Digital Textbooks are increasingly marketed and used, yet little research examines this medium. Within the limited research, even less investigates the role of digital textbooks in Mathematics a challenging content area for many students, but especially for students with visual impairments. The study method through a qualitative analysis, this study sought to understand the nature of the use of a digital algebra textbook to support secondary students with visual impairments in algebra. The results suggested that three main themes: (a) students’ dependence on their traditional textbook medium, (b) educators’ reactions to the technology, and (c) the benefits of using the digital textbook despite resistance. The three themes culminate in clear student preferences for traditional textbooks. The general discussion resistance to use of the technology warrants caution in terms of schools moving forward with the adoption of digital textbooks, and it suggests that additional examination of the topic is needed. Practitioners can consider using digital textbooks, but they will need to ensure that they and their students are both properly motivated and adequately trained to use such technology.

## **2.2. Audio Books for Students with Visual Impairment**

**Ojha Seema, S. (2015)** conducted a study on **“Creating an Effective Learning Environment for Visually Impaired Students: Assessing their Perception of Audio Books”** Education for the visually impaired is made available through the medium of sound and touch. In India educational resources for visually impaired are not many and most of the available materials are not actually accessible to them. The vast majority of visually impaired students are thus excluded from the mainstream. With a view of helping the visually impaired students have access to knowledge and information, a project was undertaken by the National Council of Educational Research and Training(NCERT).The intention was to make the textbooks accessible to these students and by converting the printed textbooks into audio books. Some organisations working in this area in India have already converted textbooks including NCERT textbooks for higher classes from IX to XII, while textbooks in Braille are available for all classes. Since audio books were not available for the

Upper Primary classes, conversion of the NCERT textbooks for classes VI-VIII into audio books, was taken up for enhancing the learning abilities of the visually impaired students which can be used along with the books in Braille. Because audio books for this stage were developed for the first time and unlike other audio books these are providing explanation of selected visuals and providing navigational facility, it was felt necessary to try out these audio books before finalization with its actual users. An effort was made in this try out study to investigate the perception of visually impaired students of these audio books.

**Ozgur, A. Z., & Gurcan, H. I. (2004)** examined “**An Audio-Book Project for Blind Students at the Open Education System of Anadolu University**” As a contemporary system to provide equal education rights to all learners, distance education gives different education opportunities to people who cannot get enough educational services because of the some limitations of traditional education. Distance education at the Open Education System of Anadolu University has been formed for all diverse people who have severely different educational needs and expectations from each other. Therefore, the system provides different educational programs and services to them, especially the people who need special education. This study conducted to develop an audio-book project for the 362 blind students in Open Education Faculty of Anadolu University. The process to convert available traditional books to audio-books, commonly known as e-audio-books, will be explained in this paper. Also, the production and publication processes of e-audio-books will be discussed.

**Subagya, S. (2017)** conducted a research on “**Design of Mathematics Audio Books for Students with Visual Impairment at the Secondary School**”. This study aimed to identify the need for accessible audio mathematics books for students with visual impairment at the secondary school. The method of this research was mixed method. The sampling technique used in this research was purposive sampling, the sample consisted of 18 visual impairment students and 15 math teachers at the secondary school for children with visual impairment from 9 provinces in Indonesia. The method used in this research was explanatory survey. The instrument validity used was content validity. Quantitative data was analyzed using descriptive statistic technique. The results showed that mathematics Braille equipped with audio or vice

versa (52.94%) with reason feel faster, more convenient. Subject to reduce the number of pages, then the audio book completeness tactual/Braille only in the form of illustrations and text are considered difficult course. Audio books are expected to be produced by the Daisy format (70.6%) with navigation full text and full audio (81.25%). The narrator could be conditioned, alternating between male and female, while the other musical equipment was presented as necessary. Most of the subjects wanted timbre narrator soft portion (75%), subjects considered most preferred medium tone frequency (100%). Media deviation is hoped can be stored on the thumb drive, hard drives and CDs (87.5%), while the most accessible media is a computer (53%). Level of difficulty 7th grade math book first semester of this when converted into audio format most difficult is the third part is the algebra (38.46%) and the level of average difficulty on all parts is 25.42%. If the book is converted into Braille format is in section 3 that the algebra (53.85%) and the difficulty level of the average on all sections is 27.21%.

**Sauer, L. (2020)** investigated “**Mathematics for visually impaired students: increasing accessibility of mathematics resources with LaTeX and Nemeth MathSpeak**” The ability to accurately read and subsequently comprehend a mathematical expression is vital to the understanding of mathematics. The Braille illiteracy rate has steadily risen among individuals with visual impairments, increasing the need for effective resources in mathematics education for such individuals. A literature review was conducted, compiling information from various resources which demonstrate the gaps in this area. Audio System for Technical Readings (AsTeR) is an existing software which can read aloud technical documents created in LaTeX, the most used typesetting application for the creation of mathematic documents. A collaboration between Abraham Nemeth’s MathSpeak guidelines for vocalizing mathematical text and AsTeR software could increase accessibility in math documents. This accessibility would create resources for students with varying visual disabilities.

### **2.3. DAISY Talking Books for Visually Impaired**

**Nasmith and Parkinson, (2008)** has done a research on the topic “**Use of Talking Books for Visually Impaired**” A different picture of the prerequisites for using talking books is found in the New Zealand study of older, visually impaired

talking book users. This study takes as its point of departure the changing demographics of New Zealand, where a large proportion of the population is and soon will be over 65 years old. This is likely to lead to greater demands on the Library of the Royal New Zealand Foundation of the Blind. As part of the library's investment in DAISY talking books, the library tested an online distribution system with a group of users aged between 40 and 93 years (mostly persons aged between 70 and 90 years). The main finding of this study was that participants welcomed the technological changes of the talking book distribution system, as it improved their access to talking books and gave them a stronger sense of independence.

Huang, P. H., Chiu, M. C., Hwang, S. L., & Wangan, J. L. (2015) conducted a research on "Investigating E-Learning Accessibility for Visually-Impaired Students: An Experimental Study" The study investigated Visual Impairment students learning difficulties in STEM Subject developed a brand new arithmetic info with the mixing of the Digital Accessible data system (DAISY). The study addressed DAISY-compliant electronic textbooks that may be displayed on a Non-Visual Desktop Access (NVDA) screen reader. Finally, a associate degree experiment was conducted for the new teaching approach. The experiment enclosed a four-day pedagogic program associate degreed an assessment session. The findings showed that the worth of the NASA-TLX subjective scales ( $t = \text{four.271}, p < 0.05$ ) was important and therefore the student accuracy rate increased . Thus the study concluded that this new methodology effectively improved vision-impaired students' proficiency in arithmetic.

#### **2.4. E- Book Accessibility Standards**

**Park, J. H., Kim, H. Y., & Lim, S. B. (2019)** conducted a research on the topic "**Development of an Electronic Book Accessibility Standard for Physically Challenged Individuals and Deduction of a Production Guideline**". Unlike popular web-based internet and mobile applications, electronic books and similar products have lower distribution and less accessibility, making them difficult for vulnerable social groups to utilize. Various institutions have proposed electronic publication (EPUB) accessibility guidelines, based on the IDEF modeling language, to provide accessible content for electronic publications. However, these are merely guidelines for securing accessibility of common electronic books. They are not geared

toward the visually impaired persons. Moreover, even if accessibility standards exist, it becomes even more difficult to then find examination tools that can fully verify standards compliance. This study established an electronic book accessibility standard for the physically challenged individuals, based on the EPUB 3.0 accessibility guideline. The author developed an automatic/semi-automatic examination tool that can test the standard. The author linked the SIGIL electronic book reader, having the highest market share in Korea, to an examination tool to verify error detection performance. Lastly, an accessibility test was performed on 50 electronic books, commercially used in the Korean electronic book market, to assess which accessibility standard domain is the most problematic. Thus, the author proposes a guideline on matters that should be considered when writing electronic books in Korea.

**Mune, C., & Agee, A. (2016)** explored **“E-books for Everyone”** The E-books Accessibility Project evaluated the major accessibility features of 16 of the most popular academic e-book platforms in academic libraries. On the positive side, most of the publishers evaluated did offer text resizing (or zoom) and were compatible with some form of screen reading technology, the most important features for users with print disabilities. Librarians are encouraged to let publishers know that accessibility is a major consideration in their e-book adoptions and urge their compliance with common accessibility standards.

**“Are e-books for everyone? An Evaluation of Academic E-Book Platforms' Accessibility Features** was conducted by **Mune, C., & Agee, A. (2016)”** This study evaluated the key accessibility options of sixteen of the foremost common tutorial e-book platforms in tutorial libraries. It had been discovered that single-publisher platforms, like air current, Palgrave, and Springer, offered a lot of accessibility options than aggregators like Pro Quest and ACLS Humanities. Each single publisher and individual platforms, however, lack basic accessibility options that business e-book suppliers have long offered, like background distinction adjustment and page reflows. On the positive facet, most of the publishers evaluated did supply text resizing (or zoom) and were compatible with some style of screen reading technology, the foremost necessary options for users with print disabilities. Librarians are inspired to let publishers recognize that accessibility may be a major

thought in their e-book adoptions and urge their compliance with common accessibility standards.

## **2.5. Accessibility Evaluation of E-Text Books**

**Sun, Y., Fritz, R. M., Yorba, L., Manabat, A. K., Katz, N. A., & Vu, K. P. L. (2017)** examine, “**E-Book Accessibility Evaluations**” The study results from accessibility evaluations of 140 publically available e-textbooks from the California Open Online Library for Education. Each textbook was evaluated for adherence to 15 Skills Commons accessibility checkpoints developed by the Multimedia Educational Resource for Learning and Online Teaching project using accessibility manuals and a scoring system developed for e-textbooks. Some books were made available in more than one format (e.g., EPUB, HTML, or PDF), and each e-textbook was evaluated in the formats that it was made available. Moreover, each book was evaluated for accessibility using assistive technologies and using non-assistive technologies. A total of 166 evaluation reports using non-assistive technologies and 163 evaluation reports using assistive technologies were produced. The study found that e-textbooks in HTML and EPUB formats were more accessible than PDF. The study also examined how the technical content of the textbook differed in terms of accessibility.

**Sun, Y. T., Manabat, A. K., Chan, M. L., Chong, I., & Vu, K. P. L. (2017)** conducted a research on the topic “**Accessibility Evaluation: Manual Development and Tool Selection for Evaluating Accessibility of E-Textbooks**” The growing availability of digital learning materials and their integration in many facets of the education system have created a need for evaluating the accessibility and usability of e-learning materials. In some cases, these digital resources are simple conversions of the original, printed materials into electronic formats. In other cases, the digital versions of the materials take advantage of the interactive abilities of the online and electronic media to enhance students’ learning experiences. Regardless of format, however, the content needs to be accessible. Although accessibility guidelines and accessibility evaluations tools are available to users, there is no comprehensive accessibility evaluation technique to help guide users in selecting the most accessible learning materials. In this study, the author surveyed existing accessibility tools, selected a recommended tool set, and created a manual for post-secondary educators, students, and other stakeholders to use for evaluating the accessibility of e-textbooks.

**Chan, M. L., Sun, Y. T., Tesoro, A. M., & Vu, K. P. L. (2017)** examine **“Development of a Scoring System for Evaluating the Accessibility of E-Textbooks”** The Internet enables educators to provide free educational resources to many users, including those with disabilities. Existing regulations outline minimum accessibility requirements. However, the author are not aware of any standard metric that would allow users to judge the relative degree of accessibility provided by e-learning materials, such as e-Textbooks. The goal of the present study was to develop an accessibility scoring method that can be used to guide users’ decision making when selecting e-Textbooks. Using both non-assistive and assistive technologies, the author analyzed a sample of 37 free access e-Textbooks using skills commons accessibility checkpoints. The authors then worked with accessibility SMEs to determine severity weightings for each checkpoint in terms of its overall accessibility impact on users. Although, the scoring technique the author developed needs further validation, it provides a starting point for accessibility researchers and post-secondary education stakeholders to quantify the level of accessibility provided by different e-Textbooks.

**Sun, Y. T., Vu, K. P. L., & Strybel, T. Z. (2017)** explored **“A Validation Test of an Accessibility Evaluation Method”** Digital materials have become a popular medium for information access, and attracted a diverse group of users, such as college students, who benefit from the low cost of, and portable access to, the materials. However, college students with disabilities may have difficulty accessing electronic materials if the materials were not developed appropriately. Laws and standards provide guidance on making digital documents accessible, but these regulations are implemented slowly. As a result, published materials on the market may have accessibility issues. Efforts have been made to produce evaluation methods for eBooks. This study assessed a newly developed accessibility evaluation methodology that was designed for e-textbooks, and examined whether Books that were rated as higher in accessibility versus books that were rated lower in accessibility resulted in differences in user experience and performance. This study consisted of 6 students with visual impairments and 6 students with normal or corrected-to-normal vision, who read and interacted with eBooks. User experience and performance were measured using subjective questionnaires, reading time, and accuracy to content-related questions. The study found differences in user experience

ratings for eBooks that were rated as high or low in accessibility; however, we found no differences in users' task performance as a function of the accessibility level of the eBook.

**Pradhan, D., Rajput, T., Rajkumar, A. J., Lazar, J., Jain, R., Morariu, V. I., & Manjunatha, V. (2022)** examined “**Development and Evaluation of a Tool for Assisting Content Creators in Making PDF Files**” Most PDF documents are inaccessible for people with disabilities, creating barriers in education, science, commerce, e-government, and recreation. Documents in PDF format are considered harder to make accessible than documents in other formats, primarily due to the insufficient tools available to assist content creators. In this article, we present the research and development of Ally, a new tool to assist content creators in remediating their PDF files to improve accessibility. This study created a more efficient and effective interaction for remediating regions, headers, reading order, and tables in a PDF document for improved accessibility. Twenty participants attempted to complete the same PDF accessibility remediation tasks using both Ally and a standard industry tool, Adobe Acrobat Pro. Ally was almost twice as fast and three times as accurate compared to Acrobat Pro, with participants reporting a strong preference for and a much higher level of satisfaction with Ally. The approaches taken in Ally improve the ability to create accessible PDFs efficiently and accurately for the four important aspects studied, but future work will need to incorporate additional functionality, related to remediating alt text, forms, and other aspects of PDF accessibility

## **2.6. Development of Accessible Books**

**Calabrò A., Contini E., Leporini B. (2009)** conducted a research on “**Book4All: A Tool to Make an E-Book More Accessible to Students with Vision/Visual-Impairments**” The study investigated that the E-books can be inadequate for blind and low vision users, especially for students. In this paper the study described a semi-automatic tool developed to support operators who adapt e-documents for visually impaired students. The proposed tool can be used to convert a PDF e-book into a more suitable accessible and usable format readable on desktop computer or on mobile devices.

**Bartalesi, V., & Leporini, B. (2015)** investigated “**An Enriched EPub E-Book for Screen Reader Users**” The aim of the study is obtaining ePub accessibility for all, including screen reader users. An ePub document is made up of several (X)HTML files, the study analysed and worked with those (X)HTML tags that affect the blind user’s experience in the reading. As a case study the study developed an “enriched” ePub book which applies technical solutions with the purpose to overcome the accessibility and usability issues observed when interacting via screen reader. In this work the author presented the results collected through an online survey conducted with 25 users to evaluate the “enriched” ePub compared with the original PDF format in terms of accessibility and usability. Positive responses about the proposed solutions emerged from the survey: the easy access to the table of content, to the images, to the text and also the ease of navigation. In short, 88 % of the users preferred the ePub format instead of the PDF. The results from the survey also showed accessibility issues and limitations of the screen readers and eBook reader software which still exist.

**Hashim, N. L., Matraf, M. S. B., & Hussain, A. (2021)** started in “**Identifying the Requirements of Visually Impaired Users for Accessible Mobile E-book Applications**” The study claimed that many e-book applications do not meet needs of the visually impaired. As a result, equitable access to e-books for the visually impaired is still limited. Hence, there is now a necessity to design usable and accessible e-book interfaces for the visually impaired. To achieve this goal, it is important to identify the e-book requirements of the visually impaired into their e-book applications. An online review was conducted involving seven visually impaired students at a local Malaysian university. The target participants’ ages are between 21 and 27 years old. The outcomes of this study identified ten requirements for accessible e-book applications for the visually impaired. Among these requirements are features that enable users to zoom, read aloud, and search for book contents. Besides that, screen reader strategy and text-to-speech are also mandatory. Other requirements include clear text and sound, ease of navigation, high contrast, and high brightness.

**Gilson, Christie L.; Dymond, Stacy K.; Chadsey, Janis G.; Hsu, Sharon Yu Fang (2007)** investigated “**Gaining Access to Textbooks for Postsecondary**

**Students with Visual Impairments**”, reported that the results from a national survey of experiences in postsecondary education of students with visual impairments in gaining access to textbooks. Participants were members of list serves sponsored by the student affiliates of the American Council of the Blind and the National Federation of the Blind. While the majority of students were successful in gaining access to their textbooks in formats they could use, a greater number reported delays in procuring textbooks. National accessible textbook providers such as Recording for the Blind & Dyslexic, <http://www.bookshare.org>, and the National Library Service for the Blind and Physically Handicapped influenced the ways in which respondents gained access to textbooks. Respondents called for quicker access to textbooks, differing formats for electronic versions, changes in how electronic texts are structured, and improvements in service delivery related to textbook conversion for offices serving students.

**Xiaoqing Gu, Bian Wu, Xiaojuan Xu (2014)** examined **“Design, development, and learning in e-Textbooks”**: what we learned and where we are going. This paper provides insights on the design, development, and learning with e-Textbooks by reviewing studies, project reports, and cases on its use. Results reveal the increased promotion and implementation of e-Textbook development in several countries. Criticisms on different e-Textbook types began during the early stages of open multimedia learning resources and digitized textbooks, and continued until the integration of information and communication technologies, authoring tools, and learning platforms. The study examined advantages of e-Textbooks and different factors that influenced e-Textbook applications. The study also reviewed the literature on learning through e-Textbooks in terms of acceptance and perception of users, and the comparison of the learning effectiveness of this format with printed textbooks. Moreover, learning in e-Textbooks is not fully realized, and requires increased in-depth studies. This paper suggests investigating the pedagogical design of e-Textbooks and further evaluation of e-Textbook functions to support learning.

**Barbara Leporini and Clara Meattin(2019)** conducted a study on **“Personalization in the Interactive EPUB 3 Reading Experience: Accessibility Issues for Screen Reader Users”**. The study investigated accessibility using EPUB 3 with particular focus on interaction via screen reader. A multimedia and interactive

EPUB 3 prototype was designed for the purpose. In particular, personalization features based on user preferences were designed to customize the reading experience and enrich the interactive experience. Despite the fact that the EPUB format is based on HTML5, and numerous guidelines for web-based technology can be applied to overcome accessibility barriers, several issues still exist with the current standard EPUB 3 when accessing via screen reader. This study contributes to digital publishing for assistive technology and reading application development by promoting accessibility in EPUB interaction.

## **2.7. Impact of Digital Talking Books on Education of Students with Visual Impairment**

**Rasheda Akhta., (2018)** examined **Education for Visually Impaired: Congeniality Study of Digital Talking Book**. Globally, Information Technology is being leveraged to empower people and improve the quality of life of the citizens regardless of their age, sex, race, social status and physical ability. The innovation of Digital Talking Book (DTB) is the contribution of that Information Technology. Digital Talking Book brings a significant advancement in favour of people who are blind or have a print disability like reduce dependency on Braille books, save time and energy, increase interest for going to school, boost up their confidence etc.

**Vojtech, R. (2016)** investigated **“Digital Barriers in Educating Students with Visual Impairment”**. Successful inclusion of the visually impaired students is significantly influenced by digital barriers in their educational environment. Provision of sighted person assistance or other support measures may help to overcome the impacts of digital barriers, however it does not comply with the inclusive approach requirements. The research aimed to examine the development of digital barriers in the university environment in 2007 - 2015. Selected conclusions of the research carried out have been subsequently compared while monitoring individual specifics and differences between the occurrence of digital barriers. The study found out that the trend in development of digital barriers is gradually deteriorating. At the same time, the author ascertained that there are no statistically significant differences in the e-Accessibility level in the countries monitored.

**Matoušek, J., Krňoul, Z., Campr, M. et al. (2020)** started in “**Speech and Web-Based Technology to Enhance Education for Pupils with Visual Impairment**” That describes a brand new web-based system specially custom-made to the education of Czech pupils with disability. The system integrates speech and language technologies with an online framework in lower educational activity, particularly in arithmetic and physics subjects. a brand new interface used the text-to-speech (TTS) synthesis for on-line automatic reading of instructional texts. The interface provides many Text-to-speech voices, synthesized information caching, and automatic process of formulas in arithmetic and physics. The system was designed to alter lecturers produce and manage teaching materials. It conjointly permits the pupils to look at and hear the scan types of these documents on-line. a college for pupils with disability participated within the development and implementation of the system. When one year of victimisation the system daily, the user expertise and analysis information were collected. The results indicate that a positive reception and frequent use of the system in addition as a preference over classical instructional materials.

## **2.8. Developing the Accessible Mathematics Content for Visually Impairment Students**

**Arlinwibowo, J., Mustaqim, Y., Prihandono, A., Hana, F. M., Ridwan, A., & Himayati, A. I. A. (2021)** explored “**Developing Mathematical Exercise Software for Visually Impaired Students**” This study aims to develop an Android-based math exercises application for the visually impaired. This research is development research carried out with research steps, namely: (1) preliminary research, (2) prototyping stage, and (3) assessment phase. The research was conducted between April 2020 and December 2020. The material chosen in the application developed was a plan taught in 8<sup>th</sup> grade. The research process involved six experts in assessing the product, namely three mathematics education experts to assess the validity of the aspects of mathematical content, two blind education experts to assess visually impaired content suitability and accessibility, and 1 IT expert to assess product performance. The product was tested on nine visually impaired. The quality of teaching materials is based on three basic aspects: feasibility, practicality, and effectiveness. The conclusions of this study are: (1) the product has good quality because it has been declared feasible by experts, practical and is effective because it

can be used to learn and measure abilities; (2) the application is divided into three sections, preamble, practice questions, and results. Application development is based on two elements, namely accessibility and compatibility of the content with the cognition of the visually impaired, (3) the question page consists of, under the question, there is a question number. There is a question; answer choices are arranged twice in two (the answer choices will be read out when pressed by the user), and (4) the visually impaired want an application that has a simple operating system, provides challenges to the user and has two functions, namely measuring their abilities and facilitating their learning.

**Maćkowski, M., Brzoza, P., Żabka, M., & Spinczyk, D. (2018)** conducted a research on **“Multimedia Platform for Mathematics Interactive Learning Accessible to Blind People”** The study shows a set of rules for describing mathematical formulas were proposed after consultation with mathematicians and teachers of blind people. The application was developed as web application. The collection of prepared exercises include about 240 prepared exercises from different areas of mathematics and 60 selected exercises including alternative description layer. About 1000 students and about 40 impaired students, from 6 faculties of the university use this platform during math courses for both self and class learning. The study shows defined rules were used to read aloud mathematical formulas to the visually impaired people with a different level of mathematical knowledge. The results confirmed good understanding of mathematical formulas by using prepared alternative

**Maćkowski, M. S., Brzoza, P. F., & Spinczyk, D. R. (2018)** explored **“Tutoring Math Platform Accessible for Visually Impaired People”** The study explains here are many problems with teaching and assessing impaired students in higher education, especially in technical science, where the knowledge is represented mostly by structural information like: math formulae, charts, graphs, etc. Developing e-learning platform for distance education solves this problem only partially due to the lack of accessibility for the blind. The article presents the accessible interactive tutoring platform for math teaching and assessment, and experience in exploring it. The results of conducted research the level of complexity of the math formulae the level of math formulae understanding is higher for alternative structural description.

The proposed solution enables alternative descriptions of math formulae. Based on the research results, the tool for computer-aided interactive learning of mathematics adapted to the needs of the blind has been designed, implemented and deployed as a platform for on-site and online and distance learning. The designed solution can be very helpful in overcoming many barriers that occur while teaching impaired students.

**Nazemi, A., Murray, I., & Mohammadi, N. (2012)** investigated **“Mathspeak: An audio Method for Presenting Mathematical Formulae to Blind Students”** This paper describes the problems involved with learning and understanding math for vision impaired students and developing a computer system approach for rendering mathematical formulae into audio form. Access to mathematics is an obstacle for blind students. The lack of easy access to mathematical resources is a barrier to higher education for many blind students and puts them at an unfair disadvantage in school, academia, and industry [1]. Results from the National Assessment of Educational Progress show that there is great disparity between the math skills of students with disabilities and students without disabilities [2]. A methodology for rendering technical documents, in particular, complex mathematical formula, in an audio descriptive form (Mathspeak) is presented in this paper.

**Armano, T., Capietto, A., Coriasco, S., Ruighi, A., & Taranto, E. (2018)** conducted a research on **“An Automatized Method Based on LaTeX for the Realization of Accessible PDF Documents Containing Formulae”** In this study the case of mathematical contents, they are not accessible at all, since formulae are usually unreadable by screen readers. Currently, a standard and fast method for inserting accessible formulae into a PDF document is still lacking despite it is a very important issue for spreading accessible digital scientific documents. In this paper, the author proposed a method for automatically generating a PDF document with mathematical contents accessible by assistive technologies for visually impaired people. By this study developed a LaTeX package that produces a final PDF document where the formulae are totally accessible by screen readers and braille displays.

**Kulkarni, M. (2019)** explored **“Digital accessibility: Challenges and Opportunities”** The study outlined barriers to digital accessibility, solutions, and

attainable next steps to making sure digital accessibility. In the context of the spherical table discussion, the study illustrated what accessibility involves, accessibility standards and tips, and spells out barriers to accessibility, as well as the restrictions displayed by the institutional context and therefore the technology context. It additionally discussed the standing of digital accessibility in Asian country.

## **2.9. Technology Aided Reading for Visually Impaired**

**Crossland, M. D., S. Silva, R., & Macedo, A. F. (2014)** conducted a research on **“Smartphone, Tablet Computer and E-Reader use by People with Vision Impairment”** An internet-based survey was advertised to people with vision impairment by word of mouth, social media, and online. Respondents were asked demographic information, what devices they owned, what they used these devices for, and what accessibility features they used. One hundred and thirty-two complete responses were received. Twenty-six percent of the sample reported that they had no vision and the remainder reported they had low vision. One hundred and seven people (81%) reported using a smartphone. Those with no vision were as likely to use a smartphone or tablet as those with low vision. Speech was found useful by 59% of smartphone users. Fifty-one percent of smartphone owners used the camera and screen as a magnifier. Forty-eight percent of the sample used a tablet computer, and 17% used an e-book reader. The most frequently cited reason for not using these devices included cost and lack of interest. Smartphones, tablet computers, and e-book readers can be used by people with vision impairment. Speech is used by people with low vision as well as those with no vision for their learning.

**Christy, B., & Pillai, A. (2021)** conducted a research on the topic **“User Feedback on Usefulness and Accessibility Features of Mobile Applications by People with Visual Impairment”**. The study aimed toward compilation a catalog of mobile applications with accessibility options. The results are expected to supply helpful insight into its usage in standard of living. This study was conducted at the Institute for Vision Rehabilitation, Hyderabad in 2 steps. In the step 1, fifty seven potentials mobile applications that were helpful for persons with visual disorder were identified. In step 2, these were explored by fifteen participants and their feedback was analyzed through SPSS applied math package. The fifty seven mobile applications were explored and rated as per the user's feedback on its usage and

accessibility options. Overall rating of general applications ranged from 2.3 to 4.55 and also the rating of exclusive applications designed for visually impaired ranged from 2.8 to 4.8. Compilation of catalog of mobile helpful code and its usage through the information generated from this study provides vital information to the first mobile users with visual disorder. The integral accessibility options of the apps that were originally developed for the final population is that the constructive move by the app developers towards inclusion. An equivalent ought to be bolstered that henceforward all-new applications to be accessible for individuals with disabilities to the quality prescribed by the online Content Accessibility pointers. Thus the study concluded that Mobile technology could be a real boon to persons with visual disorder in enhancing their independence. The catalog on accessible mobile applications developed through this study could be a valuable tool in providing data on a wider assortment of apps to new mobile users.

**Bhardwaj, R. K., & Kumar, S. (2017)** conducted a research “**A Comprehensive Digital Environment for Visually Impaired Students**” The purpose of this paper is to understand the perception of visually impaired undergraduate students about the digital environment in their institutions and develop an online information system suiting their requirements. A survey was conducted on undergraduate students enrolled in ten colleges of the University of Delhi. A total of 95 visually impaired students were interviewed individually. Data collected from the respondents were analyzed and interpreted using simple percentage method and is presented in the form of figures. The study found that maximum (35.8 percent) respondents access online electronic resources daily. In total, 51.6 percent respondents indicated that it is cumbersome to access the college website because they are not designed according to the accessibility standards developed for visually impaired students. In this study will help librarians of other universities can utilize the findings of the study to develop a comprehensive digital environment for visually impaired students.

**Ashraf, M., Hasan, N., Lewis, L., Hasan, M., & Ray, P. (2016)** investigated “**Systematic Literature Review of the Application of Information Communication Technology for Visually Impaired People**” In this study a systematic literature review provides our findings on the existing state of ICT projects

and describes outstanding issues in ICT support of VI people. The study suggest increased collaboration among healthcare professionals, caregivers, programmers, engineers, as well as policy makers; and adoption of policies in future ICT projects for VI people. A wide search of seven journal databases found a relevant cross-section of articles that were published between 2010 and 2015. The study analysed and synthesised 37 articles. The findings show the progress, awareness, interest, and issues in ICT integration to improve the quality of life for VI people. Three emergent topics for VI people are (a) assistive technology, (b) e-accessibility, and (c) virtual interfaces. The study findings suggest that ICT-aided applications can bring positive changes for VI people.

**Legge, G. E. (2016)** explored “**Reading Digital with Low Vision**” The study shows that the ongoing transition to the production and distribution of digital documents brings about new opportunities for people with visual impairment. Digital documents on computers and mobile devices permit customization of print size, spacing, font style, contrast polarity and page layout to optimize reading displays for people with low vision. As a result, the study shows that now have unprecedented opportunities to adapt text format to meet the needs of visually impaired readers.

**Adetoro, N. (2012)** examined “**Alternative Format Preferences among Visually Impaired Students**” This study adopted survey research design to investigate alternative format preferences among visually impaired students, focusing on Southwestern Nigeria. Using total enumeration technique, data were gathered from 123 students from six purposively selected secondary schools through the use of a questionnaire and an interview schedule with reliability scores ( $\alpha = 0.77$ ) and ( $\alpha = 0.75$ ) respectively. Interviews were carried out with 104 (84.5%) visually impaired students. The study found that talking books/audio recordings were the most preferred format (53%) - 51% for blind and 55% for partially sighted students respectively. Reasons for talking book preference include ease of understanding and playback, time savings, teacher’s ineptitude, difficulty and volume of Braille materials. The study recommends collaboration of libraries and other stakeholders in improving talking book collections, provision of digital talking books, Braille literacy and a national strategy for training of Braille teachers and Brailleists.

## **2.10. Screen Reading Software for Visual Impairment**

**Guha, M. S. (2017)** conducted a research on **“Effect of assistive devices on educational efficiency for persons with visual impairment”** Assistive technology is an umbrella term consisting of devices, software and services aimed at ‘assisting’ persons with disability. Such devices are of mainly three types - no, low or high tech and may be either customized, manufactured or purchased off the shelf with the aim of providing assistance and maximizing the potential of a person with disability so that he/ she may attain the highest level of functioning in multiple environments and move towards a more productive life (Cook & Polgar, 2014). The present research has made attempts to understand the role of assistive software- Non Visual Desktop Access (NVDA) which is speech synthesizer software and a scan and read device to promote usage of computers and facilitate information access among persons with visual impairment through a case study approach. Two participants with total blindness were a part of the present study in this study and made use of NVDA to work on computers and the scan and read device which made print material accessible. The results analysed using both qualitative methods reveal that such assistive technology supports individuals with disabilities to access information and participate in the educational process in a manner similar to their regular peers thereby helping them gain confidence resulting in an increased self esteem. It can be concluded that technological revolutions and advancements can thus be used for the benefit of children with exceptional needs, to promote the same patterns of life and levels of participation in them as enjoyed by their non disabled peers.

**Tagore, G. (2022)** conducted a study on **“Assistive Devices for Persons with Visual Impairment and Low Vision: Preferences and Expectations of Users in the Southern States of India”** This study focused on finding out the preferences of persons with visual impairment in selecting and using their assistive devices. It also aimed to understand their expectations and measures for assessing the utility of assistive devices. The method of the study is data was collected by using semi-structured interview schedules from 227 respondents in the Southern States of India and the Union Territory of Puducherry (Pondicherry). The expectations and suggestions made by the study sample are discussed in detail. The result of the study is that Assistive devices of any sort are considered in terms of credibility, availability and suitability. The study findings revealed that 90% of the users

preferred assistive devices such as Braille Slate-Interpoint A4, Taylor Frame, Daisy Player, JAWS Screen Reading Software, NVDA Screen Reading Software, Chessboard and Audible Cricket Ball, which were extremely helpful for their independent living. They had used most of these assistive devices in the optimal way.

**Billah, S. M., Ashok, V., Porter, D. E., & Ramakrishnan, I. V. (2017)** examined **“Ubiquitous accessibility for people with visual impairments”** This paper investigates whether technologies like screen readers have kept pace with, or have created a barrier to, the trend toward ubiquitous access, with a specific focus on desktop computing as this is still the primary way computers are used in education and employment. Towards that, the paper presents a user study with 21 visually-impaired participants, specifically involving the switching of screen readers within and across different computing platforms, and the use of screen readers in remote access scenarios. Among the findings, the study shows that, even for remote desktop access - an early forerunner of true ubiquitous access - screen readers are too limited, if not unusable. The study also identifies several accessibility needs, such as uniformity of navigational experience across devices, and recommends potential solutions. In summary, assistive technologies have not made the jump into the era of ubiquitous access, and multiple, inconsistent screen readers create new practical problems for users with visual impairments.

**Brinkley, J., & Tabrizi, N. (2017)** conducted a study on **“A Desktop Usability Evaluation of the Facebook Mobile Interface using the JAWS Screen Reader with Blind Users”** The study is to investigate this issue we have conducted a quasi-ethnographic usability evaluation of Facebook involving blind participants, the mobile interface and the JAWS screen reader on a desktop computer; a configuration that has been suggested in the related literature but insufficiently investigated. Six participants attempted 18 tasks designed to be representative of common SNS user activities. Of the features evaluated participants were most severely challenged by the process of creating a user profile and identifying other users with whom to establish relationships; two of the three core activities commonly viewed as characterizing social networking site. These findings suggest that despite recent progress additional research may be needed to make Facebook truly accessible for individuals with visual impairments.

**Robles, T. D. J. Á., Rodríguez, F. J. Á., Benítez-Guerrero, E., & Rusu, C. (2019)** investigated “**Adapting card sorting for blind people: Evaluation of the interaction design in TalkBack**” The objective of this research was to determine whether the application of a modified card sorting interaction design method with blind users can provide valuable insights into the desirable architecture of the menus in an interactive software system. For the analysis of the effectiveness of this approach, the author performed the test with 15 blind users, using a modified semi-closed card sorting method, focusing on the menu structure of specific software (Android TalkBack). As a result, the author obtained significant feedback for menu organization that included the users suggestions for new tasks and categories. Based on these data, recommend the use of the modified card sorting interaction design method to evaluate the usability of applications for blind users, because this method allows reliably defining how to select and order the menu items in an intuitive and friendly way that is specific for this type of users.

**Abraham, C. H., Boadi-Kusi, B., Morny, E. K. A., & Agyekum, P. (2021)** conducted a research “**Smartphone usage among people living with severe visual impairment and blindness**” People with vision impairments access smartphones with the help of screen reader apps such as TalkBack for Android and VoiceOver for iPhone. Prior research has mostly focused on understanding touchscreen phone adoption and typing performance of novice blind users by logging their real-world smartphone usage. Understanding smartphone usage pattern and practices of expert users can help in developing tools and tutorials for transitioning novice and intermediate users to expert users. In this work, logged smartphone usage data of eight expert Android smartphone users with visual impairments for four weeks, and then interviewed them. This paper presents a detailed analysis that uncovered novel usage patterns, such as extensive usage of directional gestures, reliance on voice and external keyboard for text input, and repurposed explore by touch for single-tap. The author concludes with design recommendations to inform the future of mobile accessibility, including hardware guidelines and rethinking accessible software design.

## **2.11. Conclusion**

The research reviewed various aspects of Accessible Text Books for students with visual impairment. The literature related to this study helped the investigator throughout the study, especially in the designing of the study and in the interpretation of the results.

## **CHAPTER III**

### **METHODOLOGY**

#### **3.0. Introduction**

Research methodology is a way to systematically solve the research problem. It refers to the design of the study through which validity of results is to be established.

Research methodology is the specific procedures or techniques used to identify, select, process, and analyze information about a topic. Methodology occupies a pivotal role in any kind of research as reliability and validity of findings depend largely on methods employed for the study.

The methodology for the present study on “**Developing Accessible Text Books for students with Visual Impairment**” involved has two stages

#### **3.1. Stages of the Study**

**Stage 1:** Developing Accessible Text Books for Students with Visual Impairment for Mathematics and Science Subjects

**Stage 2:** Compare the Digital Text Books available in Tamilnadu Government Website and Newly Developed Accessible Text Books for enhanced accessibility features Students with Visual Impairment.

**3.1.1. Stage 1:** Developing Accessible Text Books for Students with Visual Impairment for Mathematics and Science Subjects

The main objective of this study was to provide a user- friendly Text book particularly to students with visual impairment using screen readers. The development process is explained below:

##### **3.1.1.1. Phase 1 - Digital Text Book Accessibility Analysis**

Analyzed the Tamil Nadu Government State Board Curriculum 8th Grade Digital Text books of all subjects (Term 1) for accessibility features using “Accessibility Checker” .Making the Accessible Text Book of Mathematics Lesson-1 “Rational Numbers” and in Science Lesson-1 “Measurement”

**Table : 3.1 Percentage of Accessibility among All subjects of 8<sup>th</sup> Grade Text Book**

S.No	Subject	Accessibility %
1.	Tamil	60
2.	English	62
3.	Mathematics	32
4.	Science	47
5.	Social Science	56

Science and Mathematics Text Books were inaccessible in many pages Hence the study planned to analyse Mathematics and Science Text Books on Screen Reader Accessibility and Develop Accessible Text Books for Mathematics and Science Subjects of 8<sup>th</sup> Grade.

### **3.1.1.2 Phase 2: Screen Reader Accessibility Analysis of Mathematics & Science Text Books**

The following issues were noted Using Screen Readers as follows:

#### **NVDA:**

1. Read the roman letter (i) as in alphabet letter “I”, (v) as in alphabet letter “V”, (vi) as in alphabet letter “VI” etc.,
2. Did Not mention the heading levels as heading level 1 heading level 2 etc.,
3. In many pages NVDA read as “Alert empty page”(contains a scanned images).
4. Did not mention the bracket open and closed while continuously reading the sentence
5. NVDA read the bulletin list as 3 quartes.
6. Not reading the punctuation marks while continuously reading the sentence but it mention in by character wise reading.
7. Mathematics Equations were not read in NVDA is completely not reading.
8. Images were not read (missing alt text)
9. Diagrams were not read (missing alt text)
10. Flow charts were not read in proper order
11. Mind maps were not accessible.
12. Did not read the page numbers.
13. Mathematics Solutions the Answer part were not read

14. Skipping some lines, paragraph (Navigation issues).
15. QR code was not accessible.

**JAWS:**

1. JAWS read the content in the table but did not mention column and row(read randomly).
2. In many pages JAWS says “Alert this page appears to be empty”
3. Order of reading were not proper
4. Skipping some lines
5. Images were not read (missing alt text) -Says as “Graphic”
6. Diagrams were not read (missing alt text)
7. Mathematics Text book solution parts were not accessible
8. QR code was not accessible.

**TALKBACK**

1. Did not mention the bulletin list
2. Did not read the punctuation marks such as apostrophe, quotations etc.,
3. Talkback read the table but did not mention as row and column wise
4. Did not continue from where pause applied, it reads from the begging
5. Mathematics Equations were not read in correct order
6. Talkback reading the numbers first and then reading the symbols
7. Images were not read (missing alt text)
8. Diagrams were not read (missing alt text)
9. QR code was not accessible.

# Inaccessible Sample Pages of Text Book

**UNIT 1 MEASUREMENT**

**1.1 Temperature**

**1.1.1 Definition**

Temperature is a measure of the average kinetic energy of the particles in a system.

The SI unit of temperature is kelvin. 'Thermometers' are used to measure temperature directly.

Usually, thermometers are calibrated with some standard scales. Celsius, Fahrenheit, Kelvin are the most commonly used scales to measure temperature.

In these thermometers, melting point of pure ice (P.C.I) is taken as Lower Fixed Point (LFP) and boiling point of water (B.P.C) is taken as Upper Fixed Point (UFP).

**Table 1.1: Various scales to measure Temperature**

Type of Scale	Freeze Point	Boiling Point	Normal Temperature
Celsius	0°C	100°C	37°C
Fahrenheit	32°F	212°F	98.6°F
Kelvin	273 K	373 K	300 K

**1.1.2 Conversion of Scales of Temperature**

The general formula for the conversion of scale temperature is:

$$C = \frac{5}{9}(F - 32) \quad \text{and} \quad F = \frac{9}{5}C + 32$$

**1.1.3 Creating Current (i)**

Flow of electric charge, in a particular direction through a conductor, is called current.

The magnitude of an electric current is the amount of electric charge that flows through a conductor in one second.

**1.1.4 Application of various thermometric scales**

- Phenomena are classified according to a particular temperature scale.
- Scientists are using thermometers with kelvin scale.
- Common temperature measurements are made in kelvin scale. (Example: Number reports are given in kelvin scale).

**1.1.5 Rounding off**

Calculators are widely used in day to day life to do the calculations. The result given by a calculator has too many digits. Hence, the result containing more digits should be rounded off. The technique of rounding off is used in many cases of physics.

**1.1.6 Ruler for rounding off**

- Think which is the last digit to be kept.
- Leave it the same, if the next digit is 5 or greater than 5.
- Increase by one, if the next digit is 5 or greater than 5.

**1.1.7 Numerical Problem**

- Convert 100°C into kelvin.
- Convert 100 K into Celsius.
- When 1 cm of mercury rises through a column for 10 seconds, calculate the current.
- Given Charge  $Q = 2 \text{ C}$ , Time  $t = 10 \text{ s}$ .  
 $I = \frac{Q}{t} = \frac{2}{10} = 0.2 \text{ A}$   
 $I = 0.2 \text{ A}$
- Convert 100° into radian.  
 $100^\circ \times \frac{\pi}{180} = \frac{100\pi}{180} = \frac{5\pi}{9} \text{ radian}$
- Convert  $\frac{1}{2}$  into Angers.  
 $\frac{1}{2} \text{ radian} \times \frac{180}{\pi} = \frac{180}{2\pi} = \frac{90}{\pi} \text{ Angers}$
- Round off the number 1.888 to two decimal places.  
 Step 1: Identify the last digit to be kept.  
 Step 2: The following digit, i.e. 8 is less than 5. So, retain 8 as 8.
- Round off the number 1.888 to two decimal places.  
 Step 1: Identify the last digit to be kept.  
 Step 2: The following digit, i.e. 8 is greater than 5. So, increase by one. The answer is 1.89.

# Digital Text Book

**1 RATIONAL NUMBERS**

**Learning Outcomes**

- To understand the necessity for extending fractions to rational numbers.
- To represent rational numbers on the number line.
- To understand that between any two given rational numbers, there lie many rational numbers.
- To learn and perform the four basic operations on rational numbers.
- To solve the word problems on all the operations.
- To understand the properties, the additive identity and inverse and the multiplicative identity and inverse of rational numbers.
- To know how to simplify expressions with almost three brackets.

**1.1 Introduction**

Think about the situation

**Observe the following conversation:**

Pari: My dear friend Sethu, I have a doubt about fractions on the number line. Can you please clear that doubt?

Sethu: Tell me Pari, I will be happy to help you.

Pari: We know about fractions, right? Fractions like  $\frac{1}{2}$ ,  $\frac{1}{3}$ ,  $\frac{2}{3}$  are obviously clear, that  $\frac{1}{2}$  represents 1 out of 2 parts,  $\frac{1}{3}$  is 1 out of 3 parts and so on. But, where are they on the number line?

Sethu: Pari, it is easy to identify where they are on the number line. The fractions you have given here are proper fractions. Aren't they? As we know, proper fractions are greater than zero but definitely less than one.

Pari: Yes, I do agree to that, Sethu.

Sethu: Now, let me tell you where they lie on the number line. See the line that I have drawn for you.

**MATHEMATICS ALIVE**

**RATIONAL NUMBERS IN REAL LIFE**

If an orange is peeled off and 8 segments are found, then one part of it is represented by the rational number  $\frac{1}{8}$ .

An LPG domestic cylinder showing the weight of the gas and gas in decimal form.

**1.2 Rational numbers - Definition**

The collection of all numbers that can be written in the form  $\frac{a}{b}$ , where  $a$  and  $b$  are integers and  $b \neq 0$  is called rational numbers which is denoted by the letter Q. Here, the top number  $a$  is called the numerator and the bottom number  $b$  is called the denominator.

**Example:**

$\frac{1}{2}, \frac{3}{4}, \frac{-5}{7}, \frac{-11}{15}$  are some examples of rational numbers. Also, integers like  $7, -4$  and  $0$  are rational numbers as they can be written in the form  $\frac{7}{1}, \frac{-4}{1}$  and  $\frac{0}{1}$ . Mixed numbers such as  $-4\frac{2}{3}, -2\frac{1}{4}, -1\frac{3}{5}, \frac{1}{2}, \frac{7}{8}$  etc. are also rational numbers. So, all integers as well as fractions are rational numbers. The decimal numbers too, like 0.75, 1.3, 0.888 etc. are also rational numbers since they can be written in fractions form as:

$0.75 = \frac{75}{100} = \frac{3}{4}$   
 $1.3 = \frac{13}{10}$  and  $\frac{130}{100}$   
 $0.888 = \frac{888}{1000} = \frac{222}{250} = \frac{111}{125}$

In banks, home loans are given for a pre-determined interest rate as given above in decimal percentages which can be converted into rational numbers.

**Note**

The word 'ratio' is made refer to comparison of the sizes of two different quantities of any kind. For example, if there is one teacher for every 20 students in a class, then the ratio of teachers to students is 1:20. Ratios are often written as fractions and so  $1:20 = \frac{1}{20}$ . For this reason, numbers in the fractions form are called rational numbers.

**Teacher:** Pari and Sethu, I have been listening to your conversation for a while now. You have almost got everything correct! Now, we know that 0 acts as the mirror to the natural numbers (right of 0) to reflect negative integers (left of 0). By the same way, we can indicate the negative fractions on to the left of 0.

**Sethu:** I Thank you, Teacher. We have now understood what you said and know how to mark negative fractions on the number line as under:

Observing the above conversation, one can see the need of negative fractions coming into the system of numbers that we have already known about.

**Recap**

Now let us recall about Fractions

1. Write the following fractions in the appropriate boxes.

Proper fraction	Improper fraction	Mixed fraction	Negative Fraction
$\frac{4}{9}, \frac{6}{11}, \frac{2}{10}, \frac{10}{9}, \frac{-12}{4}$			

2. Which of the following is not an equivalent fraction of  $\frac{8}{12}$ ?

(A)  $\frac{2}{3}$  (B)  $\frac{16}{24}$  (C)  $\frac{32}{60}$  (D)  $\frac{24}{36}$

3. The simplest form of  $\frac{125}{100}$  is \_\_\_\_\_.

4. Which is bigger  $\frac{5}{8}$  or  $\frac{6}{7}$ ?

5. Add the fractions  $\frac{3}{5}, \frac{5}{8}, \frac{7}{10}$

6. Simplify  $\frac{1}{8} - \left( \frac{1}{6} - \frac{1}{4} \right)$

7. Multiply  $2\frac{2}{3}$  and  $\frac{1}{2}$ .

8. Divide  $\frac{7}{36}$  by  $\frac{35}{81}$ .

9. Fill in the boxes:  $\frac{70}{90} \times \frac{28}{42} = \frac{14}{15}$ ,  $\frac{84}{121} \times \frac{11}{11} = \frac{84}{121}$

10. In a city,  $\frac{7}{10}$  of the population are women and  $\frac{1}{4}$  are children. Find the fraction of the population of men.

**1.1.1 Necessity for extending fractions to rational numbers**

For the easy understanding and mathematical clarity, we shall introduce the rational numbers abstractly by focusing on two properties, namely every number has an opposite and every non-zero number has a reciprocal.

(i) Firstly, take the integers and form all possible 'fractions' where the numerators are integers and the denominators are non-zero integers. In this method, a rational number is defined as a 'ratio' of integers. The collection of rational numbers defined in this way will include the opposites of the fractions.

(ii) Secondly, we could take all the fractions together with their opposites. This would give us a new collection of numbers, called the fractions and numbers such as  $-\frac{3}{4}, -\frac{5}{9}, -\frac{13}{8}, -\frac{9}{2}, -\frac{2}{9}, \dots$  etc.

We know that, the fraction  $\frac{5}{4}$  satisfies the equation  $5x = 4$  since  $5 \times \frac{5}{4} = 4$  and  $-2$  satisfies the equation  $x + 2 = 0$ , since  $-2 + 2 = 0$ . However, there is neither a fraction nor an integer that satisfies the equation  $5x + 2 = 0$ .

We have studied about integers. We add, subtract or multiply two or more integers, you will get only an integer. If we divide two integers, we will not always get an integer. For example,  $\frac{3}{2}$  and  $\frac{2}{3}$  are not integers. These situations can be handled by extending the numbers to another collection of numbers called as rational numbers.

The following figure shows how rational numbers are an extension of the fractions and the integers.

```

    graph TD
        WholeNumbers[Whole numbers] --> PossibleQuotients1[possible quotients]
        PossibleQuotients1 --> Fractions[Fractions]
        Fractions --> Integers[Integers]
        Integers --> PossibleQuotients2[possible quotients]
        PossibleQuotients2 --> RationalNumbers[Rational numbers]
    
```

**Now, you understand that we can find an unlimited bunch of rational numbers between any two given rational numbers.**

**1.2.7 Alternative method for finding rational numbers between any two rational numbers by average concept.**

In this method, we shall use the average concept.

The average of two numbers  $a$  and  $b$  is  $\frac{a+b}{2}$ .

Let  $a$  and  $b$  be any two given rational numbers. By using the average, we can find many rational numbers between  $a$  and  $b$  as  $\frac{a+b}{2}, \frac{a+\frac{a+b}{2}}{2}, \dots$  as explained in the following:

**Example 1.2:**

Find 6 rational numbers between  $-\frac{7}{11}$  and  $\frac{5}{9}$ .

**Solution:**

L.C.M of 11 and 9 =  $11 \times 9 = 99$

$-\frac{7}{11} = \frac{-7 \times 9}{11 \times 9} = \frac{-63}{99}$   
 $\frac{5}{9} = \frac{5 \times 11}{9 \times 11} = \frac{55}{99}$

Therefore, 6 rational numbers between  $-\frac{63}{99}$  and  $\frac{55}{99}$  are  $-\frac{58}{99}, -\frac{53}{99}, -\frac{48}{99}, -\frac{43}{99}, -\frac{38}{99}, -\frac{33}{99}$ .

### **3.1.1.3 Phase 3: Development of Accessible Text Book for Students with Visual Impairment**

Mathematics and Science Text Books (Term 1) of 8<sup>th</sup> Grade were taken for the study. 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:**

**1. Titles and subtitles** (i.e. sections and subsections) 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 Text Book. It will also structure the document with ‘Hierarchy’. This means that the title of the chapter or the document is at Level 1, all following main headings are at level 2 and sub-headings of the headings will be at Level 3.

The document has also been provided with the heading structure, where the title of the document is marked at level 1, subsequent headings at level 2 and sub-headings at level 3.

Steps involved in making the heading level

- Select the text
  - Separate the line that denotes a heading from the rest of the text.
  - Place your Curser on the line to be marked as the heading.
  - Open the ‘Styles’ menu from the Home Ribbon within MS Word
  - Choose the desired heading level and click on it.
  - The line of text containing the heading will change using in-built font face, size and colour.
- 2. 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.

3. **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.

4. **Image Description:** Images were tagged and an appropriate textual description that clearly explains the information provided were given to each image.

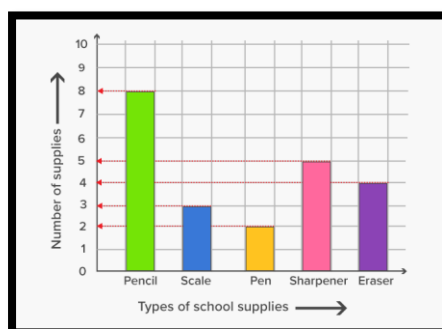
Alt text can be read by screen readers, and helps people who are blind or who have low vision understand what images and other objects are in a document. Alt texts have been used for pictures, charts, tables, shapes, in the text book.

The following steps have been followed to add alt text

- Select the object such as image, picture.
- Right click on the object selected.
- Select the format picture panel chooses the layout properties icon.
- Then choose the Alt Text, panel opens.
- Add the title for your image.
- Then add the description for your image

The alt texts used were described what is most important for the visually impaired to know in order to understand and appreciate the image that is being described. Short descriptions of to convey the important content (or) function of the were used.

**For example image description:**



Bar graph showing the types of school supplies on the x axis plotted against number of supplies shown on the y axis. The values shown on the graph are as below:

<b>X axis</b>	<b>Y axis</b>
Pencil	8
Scale	3
Pen	2
Sharpener	5
Eraser	4

Image description ends”

## 5. Tables :

Tables were 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)

### Steps followed in creating Create proper table with header to row and column

#### To add a header row to a table

1. Choose **Insert > Table** to insert a table.

Choose the number of boxes you want across to create columns, and then choose the number of boxes you want down to create rows for your table.

2. On the **Design** tab, choose the **Table Styles Options** group, and then choose **Header row**. Other options include **Banded Rows** or **Total Row**.

Now table has a header row. This means that, behind the scenes, Word and any assistive technologies can communicate intelligently about the table.

#### To Add column headings

1. Place the cursor in the first cell on the top row of your new table.
2. Type the name for this column and then press Tab to move from one column to the next. Add additional column names as needed.

Now the table has column names, which makes it easier to understand the information that the table contains. Some screen readers can be set up to read column names at any time, which can help when working with a large table.

## 6. Mathematics equation

To enhance accessibility of Maths equations two ways were followed

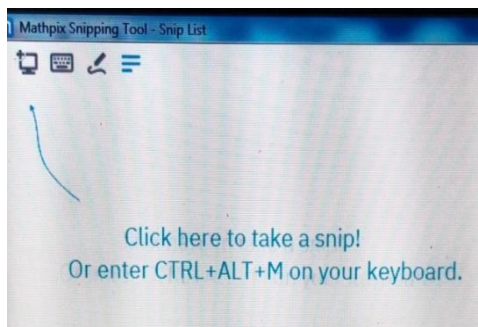
1. Small equations were directly inserted in the text book

- Solution for Mathematics equations were created using Use Mathpix Snipping tool “Mathpix”

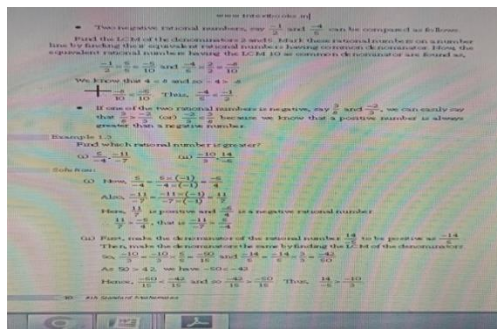
Mathpix is a Tool for an Easy and Fast Way to Create Math Equations Using LaTeX which is accessible in screen readers · *Mathpix* Snip is free (up to 50 snips per month)

Steps involved in inserting an equation into a Word document quickly and easily using Snip:

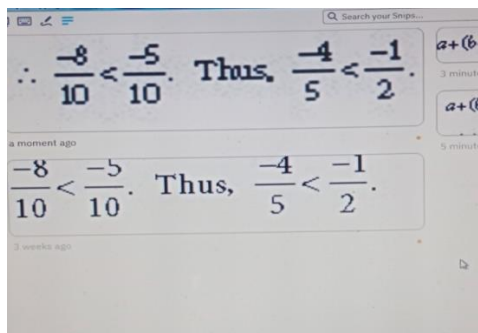
- Download the Mathpix Snipping
- Click the screenshot button or enter the shortcut ctrl+Alt+M



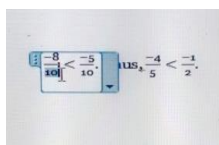
- Open the PDF document and select the equation by Click and drag the box around your desired equation to Snip it



- Copy MathML to your clipboard



5. Export the equation into word document and Paste the equation into your Word document



**3.1.2. Stage 2:** Comparison Study of Digital Text Book & Newly Developed Accessible Text Book on enhanced Accessibility features for Students with Visual Impairment.

### 3.2. Selection of Area

The samples for the study was selected from “Coimbatore District of Tamil Nadu”

### 3.3. Sample

The sample comprised of 60 people with visual impairment including 30 students with Visually Impaired Students and 30 Special Educators were selected for the study. Purposive Sampling Technique was used to select the sample.

#### ***Inclusion and Exclusion Criteria:***

Visually Impaired Students in Higher Education were only taken for the study. The Students with Visual Impairment familiar in using screen readers were only considered. The Visually Impaired Students sample consists of 15 Male and 15 Female.

The Special Educators sample consists of 30 female teachers who were familiar in using screen readers were only taken for the study.

### 3.4. Variables of the Study

Variables of the study are

#### ***3.4.1. Dependent Variable***

Over all Accessibility Features of Digital Text Book and Newly Developed Accessible text Books of Mathematics and Science subjects of 8<sup>th</sup> Grade validated by Students with Visual Impairment and Special Educators using Screen Readers.

### **3.4.2. Independent Variables**

The independent variables are Screen readers such as NVDA, JAWS, TALKBACK.

### **3.5. Design of the Study**

Comparative study was conducted to analyze the accessibility features of Tamil Nadu Government Digital Text book of Mathematics, Science and Newly Developed Accessible Text Book for Mathematics and Science subjects of 8<sup>th</sup> Grade.

### **3.6. Tool**

A rating scale consists of 20 questions assess the Accessibility Features of the Text Books 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

### **3.7. Data Collection**

#### ***Phase I:***

**Step 1:** Students with Visual Impairment were oriented to access Science and Mathematics Digital Text Books of 8<sup>th</sup> grade using 3 screen readers namely JAWS, NVDA and TALKBACK.

**Step 2:** Rating scale was administered to the students with Visual Impairment and the investigator interviewed the visually impaired students and got their rating for accessibility features of the Mathematics and Science digital text book while using different screen readers.

#### ***Phase II:***

**Step 1:** Special Educators were oriented to access Science and Mathematics Digital Text Books of 8<sup>th</sup> grade using 3 screen readers namely JAWS, NVDA and TALKBACK.

**Step 2:** Rating scale was administered to the Special Educators and filled the rating scale for accessibility features of the Mathematics and Science digital text book while using different screen readers.

***Phase III:***

**Step 1:** Students with Visual Impairment were oriented to access Newly developed Accessible Text Books for Science and Mathematics subjects of 8<sup>th</sup> grade using 3 screen readers namely JAWS,NVDA and TALKBACK.

**Step 2:** Rating scale was administered to the students with Visual Impairment and the investigator interviewed the visually impaired students and got their rating for accessibility features of the Newly Developed Mathematics and Science text book while using different screen readers.

***Phase IV:***

**Step 1:** Special Educators were oriented to access Newly developed Accessible Text Books for Science and Mathematics subjects of 8<sup>th</sup> grade using 3 screen readers namely JAWS,NVDA and TALKBACK.

**Step 2:** Rating scale was administered to the Special Educators and filled the rating scale for accessibility features of Newly Developed Accessible text Books for Mathematics and Science of 8<sup>th</sup> Grade while using different screen readers.

### **3.8. Data Analysis**

For analyzing the data, T - Test was used to

1. Compare the Overall Rating of Students with Visual Impairment on Accessibility of Digital Text Book and Newly Developed Accessible Text Books for Science and Mathematics using Screen Readers Namely JAWS, NVDA and TALKBACK.
2. Compare the Rating of Students with Visual Impairment with respect to Components namely i). Text, ii). Visual representation,iii). Content formatting, iv). Special characters, v). Accessible supports on Accessibility of Digital Text Book and Newly Developed Accessible Text Books for

Science and Mathematics using Screen Readers Namely JAWS,NVDA and TALKBACK.

3. Compare the Overall Rating of Special Educators on Accessibility of Digital Text Book and Newly Developed Accessible Text Books for Science and Mathematics using Screen Readers Namely JAWS, NVDA and TALKBACK.
4. Compare the Rating of Special Educators with respect to components namely A. Text, B. Visual representation, C. Content formatting, D. Special characters, E. Accessible supports on Accessibility of Digital Text Book and Newly Developed Accessible Text Books for Science and Mathematics using Screen Readers Namely JAWS,NVDA and TALKBACK.

### **3.9 Conclusion**

The method, tools used, sampling procedures, variables selected and administration of tool, development procedure have been clearly described in this chapter.

## CHAPTER IV

### ANALYSIS AND INTERPRETATION

#### 4.0 Introduction

This section presents the results of the examination led in the subject “Developing Accessible Text Books for Students with Visual Impairment”

Result and discussion provided a detailed description of both the research approach and the methods employed in this study in addition to a justification of their selection. The informants included in the study and an overview of the statistical techniques employed in the data analyses is given. It then outlines the results of the main effects and interaction effects of the various independent variables on the speaker evaluations.

It is an extremely useful and important part of the study because it makes possible the use of data and statistical facts have by themselves no utility. It is the interpretation that makes it possible for us to utilize collected data in various fields of activity opines (Gupta, 2005).

#### 4.1. T- Test Analysis on Accessibility of Science Text Book

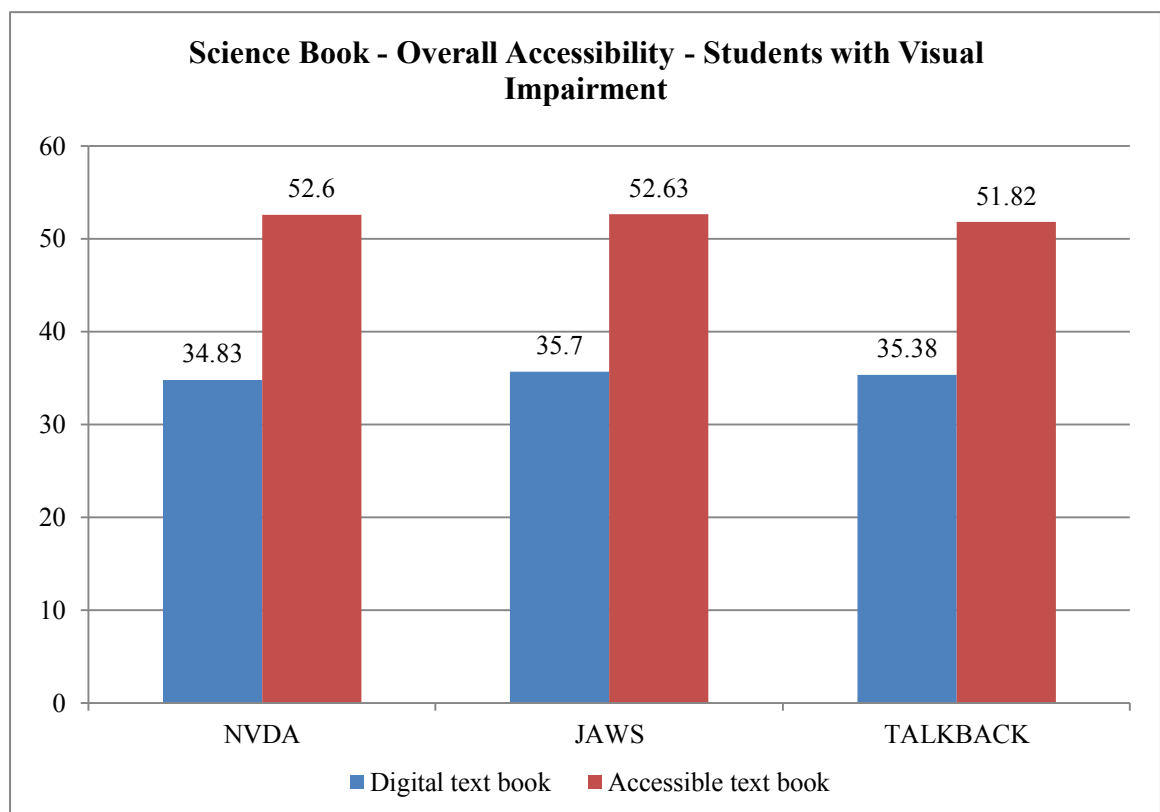
##### *4.1.1 Comparison on Overall Accessibility of Digital Text Book and Accessible Text Book for Science with Screen Readers by Students with Visual Impairment*

**Table 4.1.1 - Testing wise Mean, SD, df, t-value for Overall Accessibility of Digital Text Book and Accessible text Book of Science by Students with Visual Impairment**

Subject	Screen Readers	N	Testing	Df	Mean	S.D	t-value
Science	NVDA	30	Digital text book	29	34.83	2.151	35.54**
			Accessible Text book		52.60	2.647	
	JAWS	30	Digital text book	29	35.70	2.136	32.66**
			Accessible text book		52.63	1.921	
	TALKBACK	30	Digital text book	29	35.38	2.070	41.75**
			Accessible text book		51.82	2.156	

**\*\* Significant at 0.01 level**

From the table 4.1.1, it is evident that the t-value for Comparison on Overall Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 35.54,32.66 and 41.75 with  $df = 29$  which are significant at 0.01 level. It indicates that total tests score of Comparison on Overall Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book on Overall Accessibility 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 Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment with Screen Readers is rejected. Thus it is concluded that Newly Developed Science Accessible Text Book has better in overall accessibility accessible features than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.



**Figure 4.1.1**

**Comparison on Overall Accessibility of Science Digital Vs Accessible Text Books by Students with Visual Impairment with Screen readers**

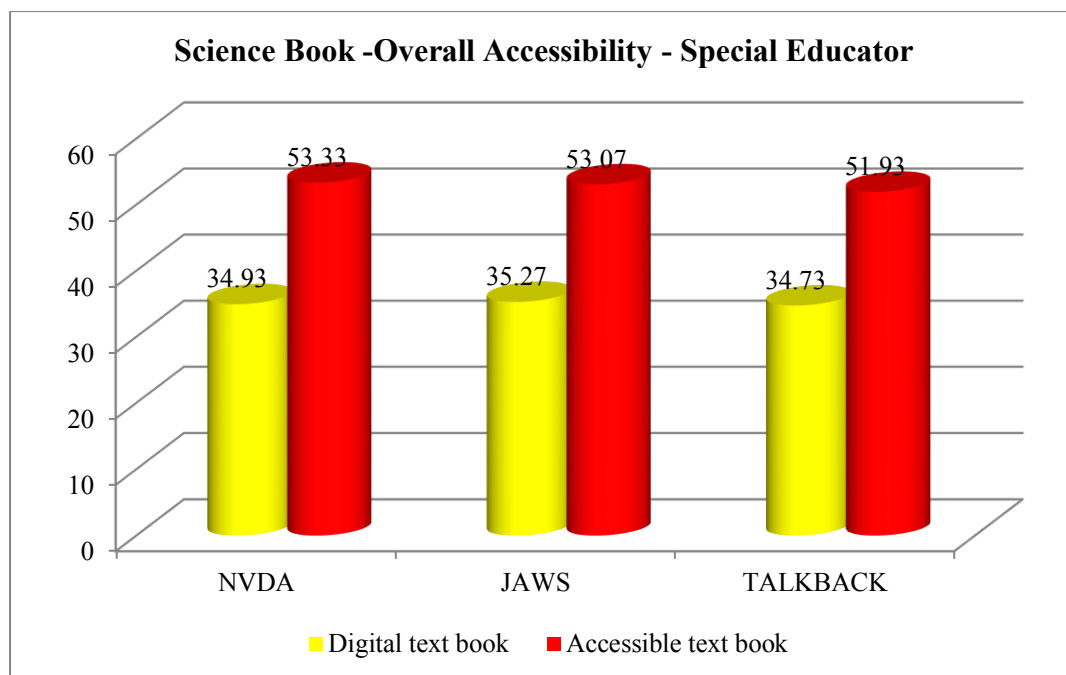
**4.1.2 Comparison on Overall Accessibility of Digital Text Book and Accessible Text Book for Science with Screen Readers by Special Educators**

**Table 4.1.2 - Testing wise Mean, SD, df, t-value on Overall Accessibility of Digital Text Book and Accessible text Book of Science by Students with Visual Impairment**

Subject	Software	N	Testing	Df	Mean	S.D	t-value
Science	NVDA	30	Digital text book	29	34.93	1.799	33.45**
			Accessible text book		53.33	2.057	
	JAWS	30	Digital text book	29	35.27	1.311	42.47**
			Accessible text book		53.07	2.180	
	TALKBACK	30	Digital text book	29	34.73	2.151	34.45* *
			Accessible text book		51.93	2.333	

**\*\* Significant at 0.01 level**

From the table 4.1.2, it is evident that the t-value for Comparison on Overall Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers namely NVDA, JAWS and TALKBACK are 33.45, 42.47 and 34.45 with  $df = 29$  which are significant at 0.01 level. It indicates that tests score of Comparison on Overall Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators 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 Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers is rejected. Thus it is concluded that the Special Educators stated that Newly Developed Science Accessible Text Book has better in overall accessibility features than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.



**Figure 4.1.2**

**Comparison on Overall Accessibility of Science Digital Vs Accessible Text Books by Special Educators with Screen readers**

#### **4.2. Component Wise T- Analysis on Accessibility of Science Text Book**

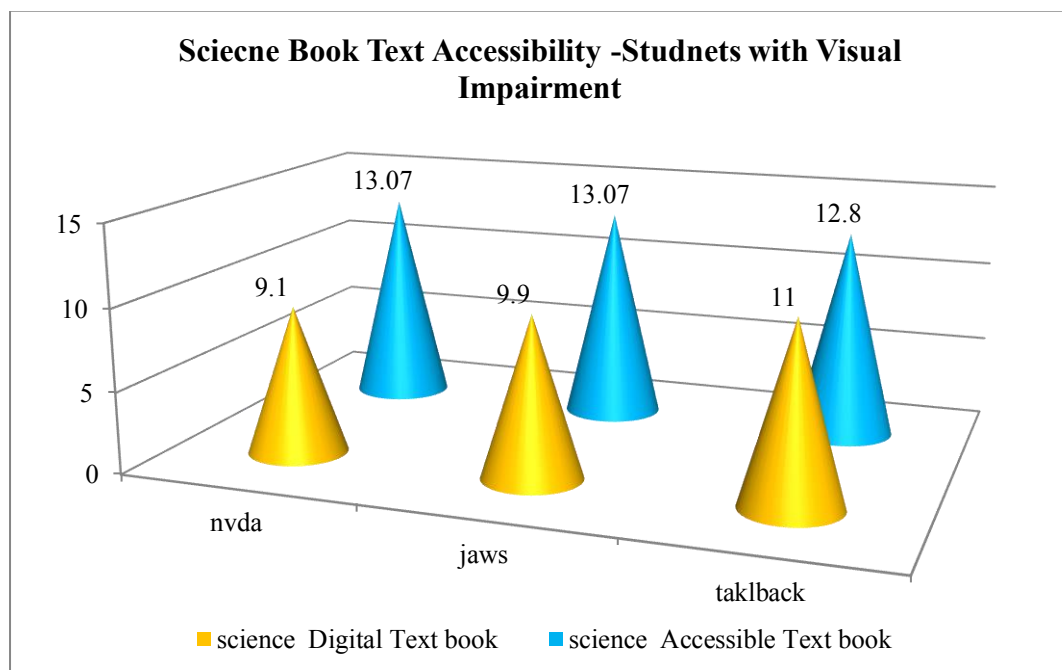
##### **4.2.1 Comparison on Text Accessibility of Digital Text Book and Accessible Text Book for Science with Screen Readers by Students with Visual Impairment**

**Table 4.2.1 - Testing wise Mean, SD, df, t-value for Text Accessibility of Digital Text Book and Accessible text Book of Science by Students with Visual Impairment**

Subject	Variables	Software	N	Testing	Df	Mean	S.D	t-value
Science	Text	NVDA	30	Digital text book	29	9.10	1.348	14.74**
				Accessible text book		13.07	.828	
		JAWS	30	Digital text book	29	9.90	1.062	12.69**
				Accessible text book		13.07	.980	
		TALKBACK	30	Digital text book	29	11.00	1.050	6.49**
				Accessible text book		12.80	.997	

**\*\* Significant at 0.01 level**

From the table 4.2.1, it is evident that the t-value for Comparison on Text Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 14.74, 12.69 and 6.49 with  $df = 29$  which are significant at 0.01 level. It indicates that tests score of Comparison on Text Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book 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 Text Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book 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 Science Accessible Text Book has better accessible features than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.



**Figure 4.2.1**

**Comparison on Text Accessibility of Science Digital Vs Accessible Text Books by Students with Visual Impairment with Screen readers**

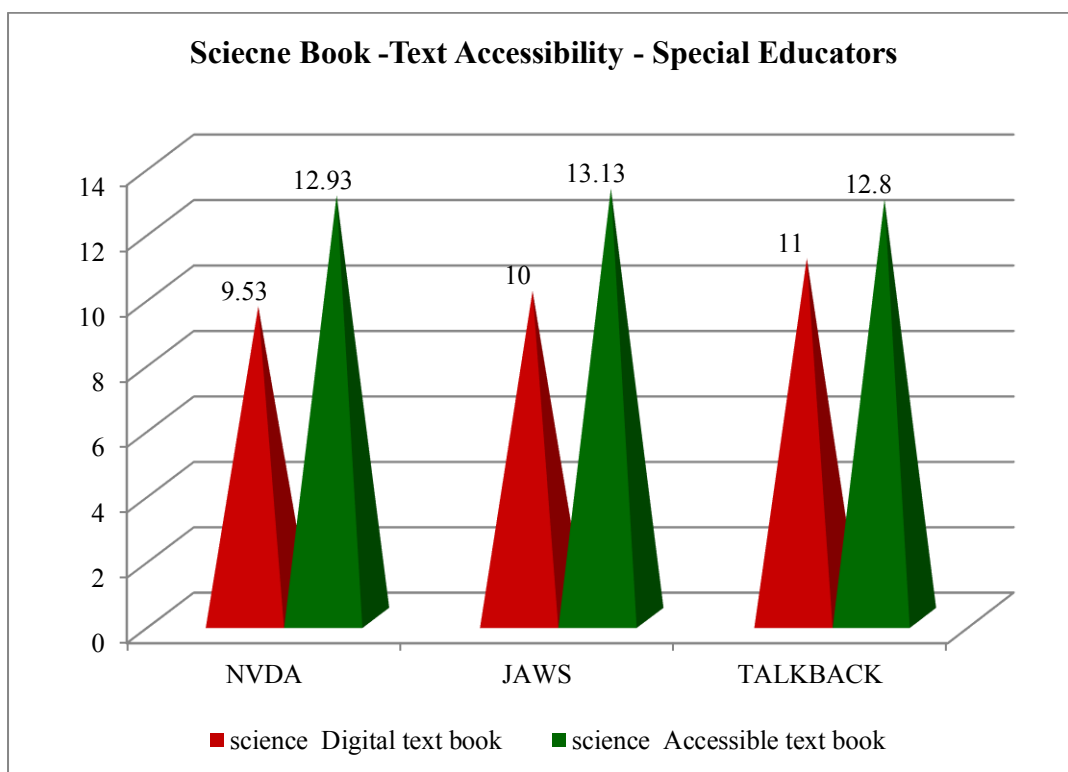
**4.2.2 Comparison on Text Accessibility of Digital Text Book and Accessible Text Book for Science with Screen Readers by Special Educators**

**Table 4.2.2 - Testing wise Mean, SD, df, t-value for Text Accessibility of Digital Text Book and Accessible text Book of Science by Special Educators**

Subject	Component	Software	N	Testing	Df	Mean	S.D	t-value
Science	Text	NVDA	30	Digital text book	29	9.53	.507	19.22**
				Accessible text book		12.93	.868	
		JAWS	30	Digital text book	29	10.00	.973	14.71**
				Accessible text book		13.13	1.232	
		TALKBACK	30	Digital text book	29	11.00	1.050	6.49**
				Accessible text book		12.80	.997	

**\*\* Significant at 0.01 level**

From the table, it is evident that the t-value for Comparison on Text Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers namely NVDA, JAWS and TALKBACK are 19.22, 14.71 and 6.49 with df = 29 which are significant at 0.01 level. It indicates that tests score of Comparison on Text Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators 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 Text Accessibility of Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers is rejected. Thus it is concluded that the Special Educators rated that the Newly Developed Science Accessible Text Book has better Text Accessibility features than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.



**Figure 4.2.2**  
**Comparison on Text Accessibility of Science Digital Vs Accessible Text Books by**  
**Special Educators with Screen readers**

**4.2.3 Comparison on Visual Representation in Digital Text Book and Accessible Text Book for Science with Screen Readers by Students with Visual Impairment**

**Table 4.2.3 - Testing wise Mean, SD, df, t-value for Visual Representation in Digital Text Book and Accessible text Book of Science by Students with Visual Impairment**

Subject	Component	Software	N	Testing	Df	Mean	S.D	t-value
Science	Visual representation	NVDA	30	Digital text book	29	8.30	1.442	14.85**
				Accessible text book		13.13	.937	
		JAWS	30	Digital text book	29	6.87	11.67	22.17**
				Accessible text book		13.53	.973	
		TALKBACK	30	Digital text book	29	6.83	.874	28.09**
				Accessible text book		12.97	.890	

**\*\* Significant at 0.01 level**

From the table 4.2.3 , it is evident that the t-value for Comparison on Visual Representation in Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 14.85, 22.17 and 28.09 with df = 29 which are significant at 0.01 level. It indicates that tests score of Visual Representation in Science Digital Text Book and Newly Developed Science Accessible Text Book 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 Visual Representation in Science Digital Text Book and Newly Developed Science Accessible Text Book 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 Science Accessible Text Book has better accessible features in Visual Representation than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.2.4 Comparison on Visual Representation in Digital Text Book and Accessible Text Book for Science with Screen Readers by Special Educators**

**Table 4.2.4 - Testing wise Mean, SD, df, t-value for Visual Representation in Digital Text Book and Accessible text Book of Science by Special Educators**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Science	Visual representation	NVDA	30	Digital text book	29	8.20	.847	34.31**
				Accessible text book		13.33	.959	
		JAWS	30	Digital text book	29	6.73	.819	26.10**
				Accessible text book		13.47	.868	
		TALKBACK	30	Digital text book	29	6.83	.874	28.09**
				Accessible text book		12.97	.890	

**\*\* Significant at 0.01 level**

From the table 4.2.4, it is evident that the t-value for Comparison on Visual Representation in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers namely NVDA, JAWS and TALKBACK are 34.31, 26.10 and 28.09 with df = 29 which are significant at 0.01 level. It indicates that tests score of Comparison on Visual Representation in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators 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 Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers is rejected. Thus it is concluded that the Special Educators rated the Newly Developed Science Accessible Text Book has better accessible features in Visual Representation than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.2.5 Comparison on Content Formatting of Digital Text Book and Accessible Text Book for Science with Screen Readers by Students with Visual Impairment**

**Table 4.2.5 - Testing wise Mean, SD, df, t-value for Content Formatting of Digital Text Book and Accessible text Book of Science by Students with Visual Impairment**

Subject	Component	Software	N	Testing	Df	Mean	S.D	t-value
Science	Content formatting	NVDA	30	Digital text book	29	8.20	.847	9.35**
				Accessible text book		10.80	1.095	
		JAWS	30	Digital text book	29	8.20	.805	12.57**
				Accessible text book		10.67	.606	
		TALKBACK	30	Digital text book	29	8.20	.805	12.15**
				Accessible text book		10.57	1.040	

**\*\* Significant at 0.01 level**

From the table 4.2.5, it is evident that the t-value for Comparison on Content Formatting in Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 9.35, 12.57 and 12.15 with df = 29 which are significant at 0.01 level. It indicates that tests score of Comparison on Content Formatting in Science Digital Text Book and Newly Developed Science Accessible Text Book 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 Content Formatting in Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment with Screen Readers is rejected. Thus it is concluded that the Students with Visual Impairment rate that the Newly Developed Science Accessible Text Book has better accessible features in content formatting than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.2.6 Comparison on Content Formatting of Digital Text Book and Accessible Text Book for Science with Screen Readers by Special Educators**

**Table 4.2.6 - Testing wise Mean, SD, df, t-value for Content Formatting of Digital Text Book and Accessible text Book of Science by Special Educators**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Science	Content formatting	NVDA	30	Digital text book	29	8.20	1.064	8.50**
				Accessible text book		10.93	.944	
		JAWS	30	Digital text book	29	7.80	.925	16.48**
				Accessible text book		11.00	.525	
		TALKBACK	30	Digital text book	29	8.20	.805	12.15**
				Accessible text book		10.57	1.040	

**\*\* Significant at 0.01 level**

From the table 4.2.6, it is evident that the t-value for Comparison on Content Formatting in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers namely NVDA, JAWS and TALKBACK are 8.50, 16.48 and 12.15 with df = 29 which are significant at 0.01 level. It indicates that tests score of Content Formatting in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers differ significantly. In the light of the null hypothesis that there is no significant difference between the mean score of Content Formatting in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers Screen Readers is rejected. Thus it is concluded that the Special educators rated that the Newly Developed Science Accessible Text Book has better accessible features in Content formatting than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.2.7 Comparison on Special Characters Accessibility in Digital Text Book and Accessible Text Book for Science with Screen Readers by Students with Visual Impairment**

**Table 4.2.7 - Testing wise Mean, SD, df, t-value for Special Characters Accessibility of Digital Text Book and Accessible text Book of Science by Students with Visual Impairment**

Subject	Component	Software	N	Testing	Df	Mean	S.D	t-value
Science	Special characters	NVDA	30	Digital text book	29	4.03	.928	20.50**
				Accessible text book		7.80	.761	
		JAWS	30	Digital text book	29	5.60	.770	8.42**
				Accessible text book		7.53	.860	
		TALKBACK	30	Digital text book	29	4.50	.770	13.67**
				Accessible text book		7.60	.900	

**\*\* Significant at 0.01 level**

From the table 4.2.7, it is evident that the t-value for Comparison on Special Characters Accessibility in Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 20.50, 8.42 and 13.67 with df = 29 which are significant at 0.01 level. It indicates that tests score of in Science Digital Text Book and Newly Developed Science Accessible Text Book 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 in Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment with Screen Readers is rejected. Thus the Students with Visual Impairment concluded that the Newly Developed Science Accessible Text Book has better accessible features in Special Characters Accessibility than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.2.8 Comparison on Special Characters Accessibility in Digital Text Book and Accessible Text Book for Science with Screen Readers by Special Educators**

**Table 4.2.8 - Testing wise Mean, SD, df, t-value for Special Characters Accessibility of Digital Text Book and Accessible text Book of Science by Special Educaotrs**

Subject	Component	Software	N	Testing	Df	Mean	S.D	t-value
Science	Special characters	NVDA	30	Digital text book	29	4.00	.643	20.61**
				Accessible text book		8.07	.785	
		JAWS	30	Digital text book	29	5.80	.551	9.79**
				Accessible text book		7.73	.691	
		TALKBACK	30	Digital text book	29	4.50	.900	13.67**
				Accessible text book		7.60	.770	

**\*\* Significant at 0.01 level**

From the table 4.2.8, it is evident that the t-value for Comparison on Special Characters Accessibility in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers namely NVDA, JAWS and TALKBACK are 20.61, 9.79 and 13.67 with df = 29 which are significant at 0.01 level. It indicates that tests score of Comparison on Special Characters Accessibility in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators 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 Special Characters Accessibility in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers is rejected. Thus the Special Educators concluded that Newly Developed Science Accessible Text Book has better accessible features in Special Characters Accessibility than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.2.9 Comparison on Accessibility Support in Digital Text Book and Accessible Text Book for Science with Screen Readers by Students with Visual Impairment**

**Table 4.2.9 - Testing wise Mean, SD, df, t-value for Accessibility Support in Digital Text Book and Accessible text Book of Science by Students with Visual Impairment**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Science	Accessible support	NVDA	30	Digital text book	29	5.20	.761	12.24**
				Accessible text book		7.80	.847	
		JAWS	30	Digital text book	29	5.13	.747	14.01**
				Accessible text book		7.83	.819	
		TALKBACK	30	Digital text book	29	5.00	1.050	6.49**
				Accessible text book		7.80	.997	

**\*\* Significant at 0.01 level**

From the table 4.2.9, it is evident that the t-value for Comparison on Accessibility Support in Science Digital Text Book and Newly Developed Science Accessible Text Book by Students with Visual Impairment with Screen Readers NVDA, JAWS and TALKBACK are 12.24, 14.01 and 6.49 with df = 29 which are significant at 0.01 level. It indicates that tests score of Comparison on Accessibility Support in Science Digital Text Book and Newly Developed Science Accessible Text Book 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 Accessibility Support in Science Digital Text Book and Newly Developed Science Accessible Text Book 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 Science Accessible Text Book has better accessible features in Accessibility Support than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.2.10 Comparison on Accessibility Support in Digital Text Book and Accessible Text Book for Science with Screen Readers by Special Educators**

**Table 4.2.10 - Testing wise Mean, SD, df, t-value for Accessibility Support in Digital Text Book and Accessible text Book of Science by Special Educators**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Science	Accessible support	NVDA	30	Digital text book	29	5.00	.910	12.32**
				Accessible text book		8.07	.785	
		JAWS	30	Digital text book	29	4.93	.583	18.10**
				Accessible text book		7.73	.691	
		TALKBACK	30	Digital text book	29	5.17	.791	11.05**
				Accessible text book		7.83	.834	

**\*\* Significant at 0.01 level**

From the table 4.2.10, it is evident that the t-value for Comparison on Accessibility Support in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers NVDA, JAWS and TALKBACK Screen Readers are 12.32, 18.10 and 11.05 with df = 29 which are significant at 0.01 level. It indicates that tests score of Comparison on Accessibility Support in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators 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 Accessibility Support in Science Digital Text Book and Newly Developed Science Accessible Text Book by Special Educators with Screen Readers is rejected. Thus it is concluded that Newly Developed Science Accessible Text Book has better accessible features in Accessibility Support than the Science Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

### 4.3. T- Test Analysis on Accessibility of Mathematics Text Book

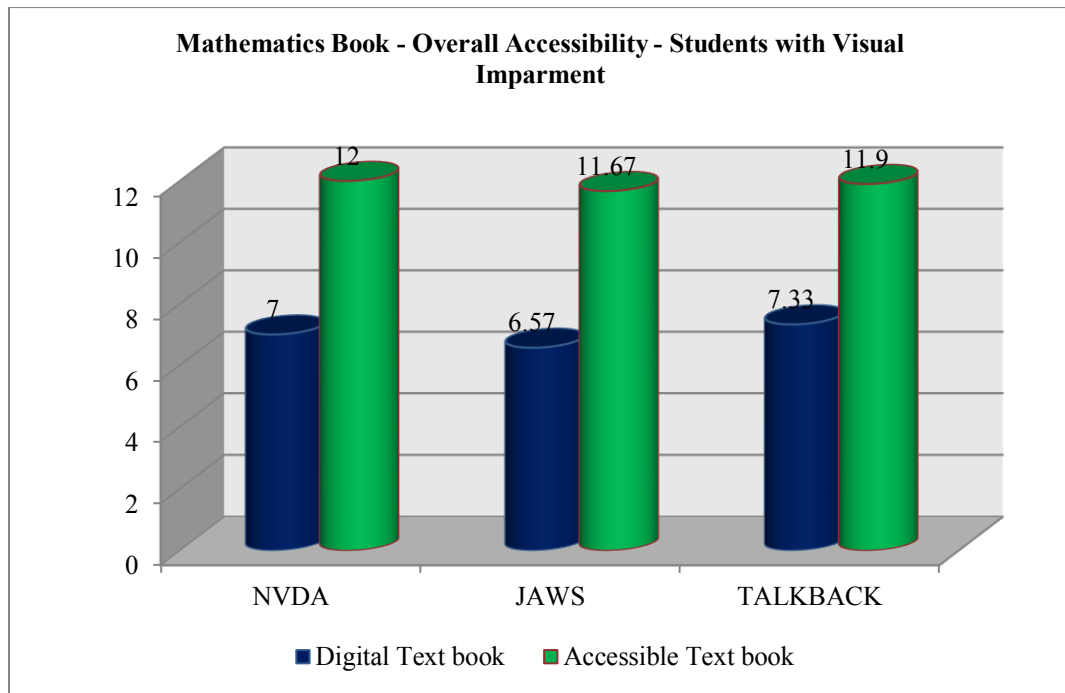
#### 4.3.1 Comparison on Overall Accessibility of Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Students with Visual Impairment

**Table 4.3.1 - Testing wise Mean, SD, df, t-value for Overall Accessibility of Digital Text Book and Accessible text Book of Mathematics by Students with Visual Impairment**

Subject	Software	N	Testing	Df	Mean	S.D	t-value
Maths	NVDA	30	Digital text book	29	27.63	1.921	34.52**
			Accessible text book		48.57	2.285	
	JAWS	30	Digital text book	29	27.23	2.063	40.81**
			Accessible text book		48.63	1.956	
	TALKBACK	30	Digital text book	29	29.30	2.423	36.72**
			Accessible text book		48.60	1.850	

\*\* *Significant at 0.01 level*

From the table 4.3.1, it is evident that the t-value for Comparison on Overall Accessibility of Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and 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 Text Book and Newly Developed Mathematics Accessible Text Book 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 Text Book and Newly Developed Mathematics Accessible Text Book 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.



**Figure 4.3.1**

**Comparison on Overall Accessibility of Mathematics Digital Vs Accessible Text Books by Students with Visual Impairment with Screen readers**

**4.3.2 Comparison on Overall Accessibility of Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Special Educators**

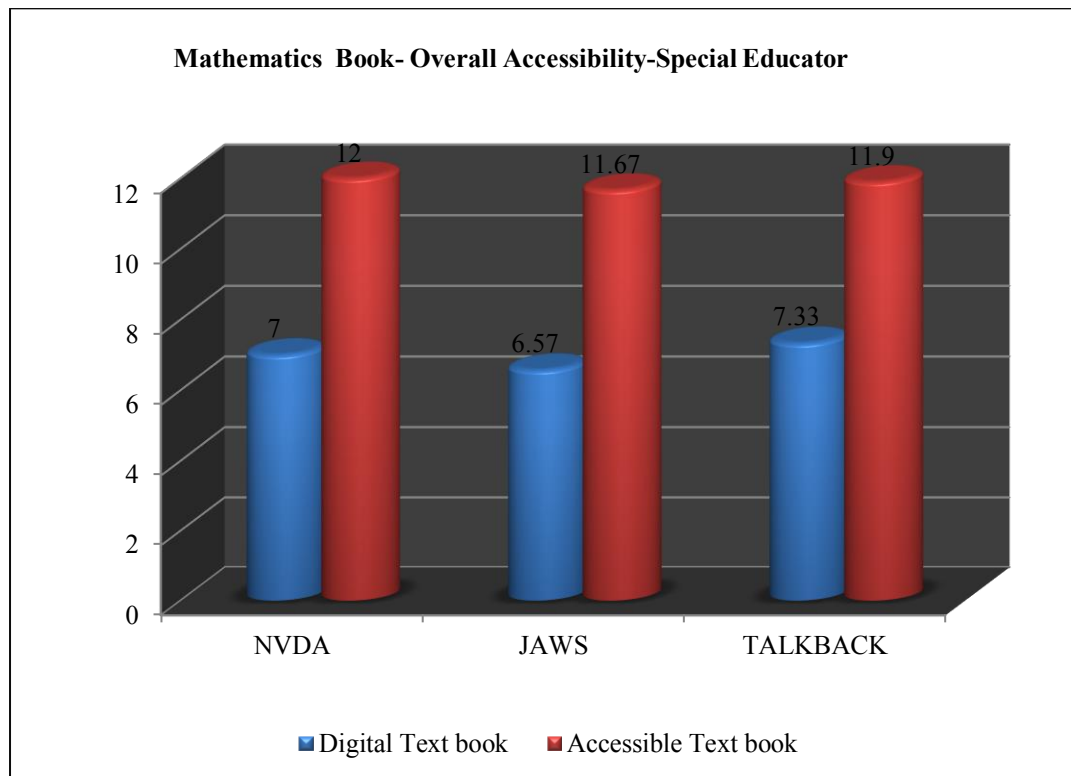
**Table 4.3.2 Testing wise Mean, SD, df, t-value for Overall Accessibility of Digital Text Book and Accessible text Book of Mathematics by Special Educators**

Subject	Software	N	Testing	Df	Mean	S.D	t-value
Maths	NVDA	30	Digital text book	29	28.20	2.203	38.90**
			Accessible text book		48.43	2.112	
	JAWS	30	Digital text book	29	27.23	2.176	4.80**
			Accessible text book		48.10	2.369	
	TALKBACK	30	Digital text book	29	29.93	2.463	47.66**
			Accessible text book		48.57	1.813	

**\*\* Significant at 0.01 level**

From the table 4.3.2, it is evident that the t-value for Comparison on Overall Accessibility of Mathematics Digital Text Book and Newly Developed Mathematics

Accessible Text Book by Special Educators with Screen Readers namely NVDA, JAWS and TALKBACK are 38.90, 4.80 and 47.66 with  $df = 29$  which are significant at 0.01 level. It indicates that total tests score of Comparison on Overall Accessibility of Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators 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 Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators with Screen Readers is rejected. Thus it is concluded that the Special Educators rated that the Newly Developed Mathematics Accessible Text Book has better Overall accessibility features than the Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.



**Figure 4.3.2**

**Comparison on Overall Accessibility of Mathematics Digital Vs Accessible Text Books by Special Educators with Screen readers**

#### 4.4. Component Wise T- Test Analysis on Accessibility of Mathematics Text Book

##### 4.4.1 Comparison on Text Accessibility of Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Students with Visual Impairment

**Table 4.4.1 - Testing wise Mean, SD, df, t-value for Text Accessibility of Digital Text Book and Accessible text Book of Mathematics by Students with Visual Impairment**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Text	NVDA	30	Digital text book	29	7.37	.964	25.51**
				Accessible text book		12.17	.986	
		JAWS	30	Digital text book	29	6.90	.923	19.19**
				Accessible text book		12.20	1.324	
		TALKBACK	30	Digital text book	29	7.63	1.245	13.27**
				Accessible text book		12.17	1.262	

\*\* Significant at 0.01 level

From the table 4.4.1, it is evident that the t-value for Comparison on Text Accessibility of Mathematics Digital Text Book 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 Text Book and Newly Developed Mathematics Accessible Text Book 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 Text Book and Newly Developed Mathematics Accessible Text Book 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.

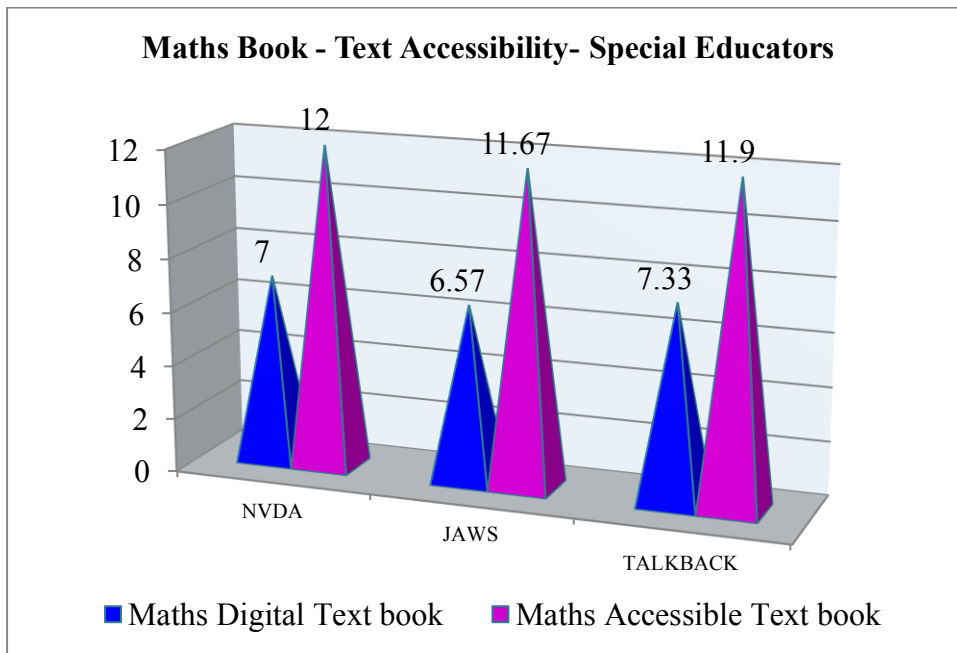
#### 4.4.2 Comparison on Text Accessibility of Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Special Educators

**Table 4.4.2 - Testing wise Mean, SD, df, t-value for Text Accessibility of Digital Text Book and Accessible text Book of Mathematics by Special Educators**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Text	NVDA	30	Digital text book	29	7.07	1.053	16.15**
				Accessible text book		12.17	1.311	
		JAWS	30	Digital text book	29	7.27	1.015	15.39**
				Accessible text book		11.80	1.186	
		TALKBACK	30	Digital text book	29	7.47	1.279	14.03**
				Accessible text book		11.97	1.129	

**\*\* Significant at 0.01 level**

From the table 4.4.2, it is evident that the t-value for Comparison on Text Accessibility of Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators with Screen Readers namely NVDA, JAWS and TALKBACK are 16.15, 15.39 and 14.03 with df = 29 which are significant at 0.01 level. It indicates that total tests score of Comparison on Text Accessibility of Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators with Screen Readers differ significantly. In the light of the null hypothesis that there is no significant difference between the mean score of is rejected. Thus it is concluded in the view of Special Educators the Newly Developed Mathematics Accessible Text Book has better accessible features in Text accessibility than the Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.



**Figure 4.4.1**

**Comparison on Text Accessibility of Mathematics Digital Vs Accessible Text Books by Special Educators with Screen readers**

**4.4.3 Comparison on Visual Representation in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Students with Visual Impairment**

**Table 4.4.3 - Testing wise Mean, SD, df, t-value for Visual Representation in Digital Text Book and Accessible text Book of Mathematics by Students with Visual Impairment**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Visual representation	NVDA	30	Digital text book	29	6.47	1.137	18.09**
				Accessible text book		12.33	1.213	
		JAWS	30	Digital text book	29	6.60	1.276	20.72**
				Accessible text book		12.37	1.159	
		TALKBACK	30	Digital text book	29	7.20	1.270	19.61**
				Accessible text book		12.07	1.311	

**\*\* Significant at 0.01 level**

From the table 4.4.3, it is evident that the t-value for Comparison on Visual Representation in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book 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 Text Book and Newly Developed Mathematics Accessible Text Book 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 Text Book 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.

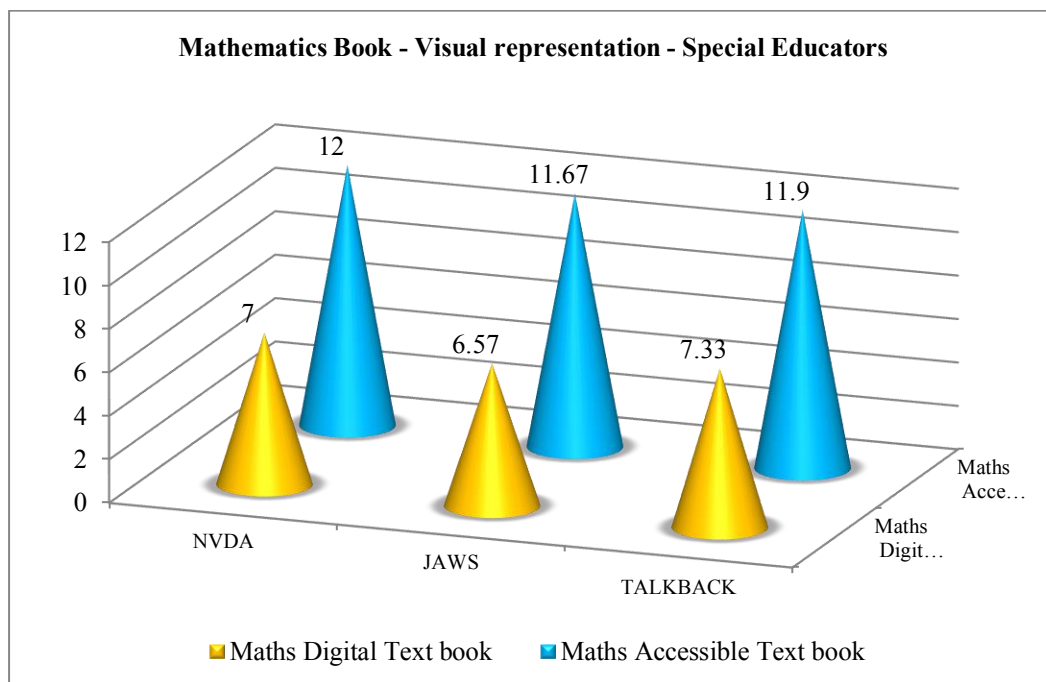
**4.4.4 Comparison on Visual Representation in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by special Educator**

**Table 4.4.4 - Testing wise Mean, SD, df, t-value for Visual Representation in Digital Text Book and Accessible text Book of Mathematics by Special Educator**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Visual representation	NVDA	30	Digital text book	29	7.00	.947	20.02**
				Accessible text book		12.03	1.129	
		JAWS	30	Digital text book	29	6.57	.971	23.02**
				Accessible text book		11.67	1.028	
		TALKBACK	30	Digital text book	29	7.33	1.269	19.34**
				Accessible text book		11.93	1.081	

**\*\* Significant at 0.01 level**

From the table 4.4.4, it is evident that the t-value for Comparison on Visual Representation in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 20.02, 23.02 and 19.34 with df = 29 which are significant at 0.01 level. It indicates that total tests score of Comparison on Visual Representation in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book 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 Text Book 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 Visual Representation than the Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.



**Figure 4.4.2**

**Comparison on Visual Representation of Mathematics Digital Vs Accessible Text Books by Special Educators with Screen readers**

**4.4.5 Comparison on Content Formatting in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Students with Visual Impairment**

**Table 4.4.5 - Testing wise Mean, SD, df, t-value for Content Formatting in Digital Text Book and Accessible text Book of Mathematics by Students with Visual Impairment**

Subject	Component	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Content formatting	NVDA	30	Digital text book	29	5.30	.952	15.60**
				Accessible text book		9.70	.952	
		JAWS	30	Digital text book	29	5.30	.952	18.36**
				Accessible text book		9.77	.858	
		TALKBACK	30	Digital text book	29	5.87	1.167	15.03**
				Accessible text book		9.97	.850	

**\*\* Significant at 0.01 level**

From the table 4.4.5, it is evident that the t-value for Comparison on Content Formatting in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 15.60, 18.36 and 15.03 with df = 29 which are significant at 0.01 level. It indicates that tests score of Comparison on Content Formatting in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book 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 Content Formatting in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book 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 in Content Formatting features than the Mathematics Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.4.6 Comparison on Content Formatting in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Special Educator**

**Table 4.4.6 - Testing wise Mean, SD, df, t-value for Content Formatting in Digital Text Book and Accessible text Book of Mathematics by Special Educator**

Subject	Component	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Content formatting	NVDA	30	Digital text book	29	5.67	.922	15.55**
				Accessible text book		9.80	.925	
		JAWS	30	Digital text book	29	5.33	.959	21.13**
				Accessible text book		9.93	1.015	
		TALKBACK	30	Digital text book	29	6.00	1.083	14.08**
				Accessible text book		9.97	.999	

**\*\* Significant at 0.01 level**

From the table 4.4.6, it is evident that the t-value for le 4.4.5, it is evident that the t-value for Comparison on Content Formatting in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators with Screen Readers namely NVDA, JAWS and TALKBACK are 15.55, 21.13 and 14.08 with  $df = 29$  which are significant at 0.01 level. It indicates that total tests score of Comparison on Content Formatting in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators 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 Content Formatting in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators with Screen Readers is rejected. Thus it is concluded that the Special Educators rated that the Newly Developed Mathematics Accessible Text Book has better Content Formatting features than the Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.4.7 Comparison on Special Characters Accessibility in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Students with Visual Impairment**

**Table 4.4.7 - Testing wise Mean, SD, df, t-value for Special Characters Accessibility in Digital Text Book and Accessible text Book of Mathematics by Students with Visual Impairment**

Subject	Component	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Special characters	NVDA	30	Digital text book	29	3.97	.850	14.35**
				Accessible text book		7.10	.803	
		JAWS	30	Digital text book	29	4.07	.740	14.08**
				Accessible text book		7.20	.714	
		TALKBACK	30	Digital text book	29	4.30	.837	13.67**
				Accessible text book		7.27	.907	

**\*\* Significant at 0.01 level**

From the table 4.4.7, it is evident that the t-value for Comparison on Special Characters Accessibility in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK Screen Readers are 14.35, 14.08 and 13.67 with  $df = 29$  which are significant at 0.01 level. It indicates that tests score of Comparison on Special Characters Accessibility in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book 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 Special Characters Accessibility in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book 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 Special Characters Accessibility features than the Mathematics

Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.4.8 Comparison on Special Characters Accessibility in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Special Educators**

**Table 4.4.8 - Testing wise Mean, SD, df, t-value for Special Characters Accessibility in Digital Text Book and Accessible text Book of Mathematics by Special Educators**

Subject	Component	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Special characters	NVDA	30	Digital text book	29	4.13	.819	17.06**
				Accessible text book		7.23	.679	
		JAWS	30	Digital text book	29	3.87	.819	16.15**
				Accessible text book		7.47	.860	
		TALKBACK	30	Digital text book	29	4.43	.728	15.64**
				Accessible text book		7.43	.971	

**\*\* Significant at 0.01 level**

From the table 4.4.8, it is evident that the t-value for Comparison on Special Characters Accessibility in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators with Screen Readers namely NVDA, JAWS and TALKBACK Screen Readers are 17.06, 16.15 and 15.64 with df = 29 which are significant at 0.01 level. It indicates that total tests score of Comparison on Special Characters Accessibility in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators 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 Special Characters Accessibility in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Special Educators with Screen Readers is rejected. Thus it is concluded that the Special Educators stated that the Newly Developed Mathematics Accessible Text Book has better accessible features in Special Characters than the Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.4.9 Comparison on Accessibility Support in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Students with Visual Impairment**

**Table 4.4.9 - Testing wise Mean, SD, df, t-value for Accessibility Support in Digital Text Book and Accessible text Book of Mathematics by Students with Visual Impairment**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Accessible support	NVDA	30	Digital text book	29	4.53	.860	11.65**
				Accessible text book		7.27	.785	
		JAWS	30	Digital text book	29	4.37	.809	13.10**
				Accessible text book		7.10	.759	
		TALKBACK	30	Digital text book	29	4.30	.877	15.21**
				Accessible text book		7.13	.730	

**\*\* Significant at 0.01 level**

From the table 4.4.9, it is evident that the t-value for Comparison on Accessibility Support in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 11.65, 13.10 and 15.21 with df = 29 which are significant at 0.01 level. It indicates that tests score of Comparison on Accessibility Support in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book 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 Accessibility Support in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers is rejected. Thus the Students with Visual Impairment rated that the Newly Developed Mathematics Accessible Text Book has better features Accessibility Support than the Mathematics Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.4.10 Comparison on Accessibility Support in Digital Text Book and Accessible Text Book for Mathematics with Screen Readers by Special Educators**

**Table 4.4.10 - Testing wise Mean, SD, df, t-value for Accessibility Support in Digital Text Book and Accessible text Book of Mathematics by Special Educators**

Subject	Components	Software	N	Testing	Df	Mean	S.D	t-value
Maths	Accessible support	NVDA	30	Digital text book	29	4.33	.610	15.07**
				Accessible text book		7.20	.758	
		JAWS	30	Digital text book	29	4.20	.805	17.90**
				Accessible text book		7.23	.679	
		TALKBACK	30	Digital text book	29	4.70	.583	19.31**
				Accessible text book		7.27	.651	

**\*\* Significant at 0.01 level**

From the table, it is evident that the t-value for Comparison on Accessibility Support in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK are 15.07, 17.90 and 19.31 with df = 29 which are significant at 0.01 level. It indicates that total tests score of Comparison on Accessibility Support in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book 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 Accessibility Support in Mathematics Digital Text Book and Newly Developed Mathematics Accessible Text Book by Students with Visual Impairment with Screen Readers is rejected. Thus the Special Educators rated that the Newly Developed Mathematics Accessible Text Book has better features in Accessibility Support than the Digital Text Book with all three Screen Readers namely NVDA, JAWS and TALKBACK.

**4.5 Conclusion**

The findings of the study were summarized and presented in next chapter.

## **CHAPTER V**

### **SUMMARY AND CONCLUSION**

#### **5.0. Introduction**

The study has resulted that some information which may be utilized in improving the present state of affairs in the education of student with Visual Impairment. Hence, the study analyzed “Developing Accessible Text Books for Students with Visual Impairment” The summary and conclusion arrived out of the analysis are presented under the following headings.

#### **5.1. Objectives of the Study**

The major objectives of the study were to

1. Analyze the Accessibility in Digital Text book of Science subject available in Tamilnadu Government Text Books using screen readers namely JAWS, NVDA and TALKBACK.
2. Analyze the Accessibility in Digital Text book of Mathematic Subject available in Tamilnadu Government Text Books using screen readers namely JAWS, NVDA and TALKBACK.
3. Develop an Accessible Science Text Book for Students with Visual Impairment.
4. Develop an Accessible Mathematics Text Book for students with Visual Impairment.
5. Compare the Accessibility of Digital Books and Newly Developed Accessible Text Book of Science Subject Screen Readers such as JAWS, NVDA and TALKBACK.
6. Compare the Accessibility of Digital Text Book and Newly Developed Accessible Text Book of Mathematics using Screen Readers such as JAWS, NVDA and TALKBACK.
7. Compare the Accessibility of Digital Text Book and Newly Developed Accessible Text Book for Science with respect Text, Visual representation,

Content formatting, Special characters, Accessible support for Accessibility using Screen readers such as JAWS, NVDA and TALKBACK.

8. Compare the Accessibility of Digital Text Book and Newly Developed Accessible Text Book for Mathematics with respect to Text, Visual representation, Content formatting, Special characters, Accessible support for Accessibility using Screen readers such as JAWS, NVDA and TALKBACK.

## **5.2. Methodology**

The methodology for the present study on **“Developing Accessible Text Books for students with Visual Impairment”** involved has two stages

**5.2.1 Stage 1** - Develop Accessible Text Books for Students with Visual Impairment for Mathematics and Science Subjects. The main objective of this study was to provide a user- friendly Text book particularly to students with visual impairment using screen readers. Stage 1 consists of 3 phases,

**Phase 1** - Digital Text Book Accessibility Analysis- In this phase, the Tamil Nadu Government State Board Curriculum 8th Grade Digital Text books of all subjects (Term 1) for accessibility features using “Accessibility Checker” has been analyzed.

Science and Mathematics Text Books were inaccessible in many pages Hence the study planned to analyse Mathematics and Science Text Books on Screen Reader Accessibility and Develop Accessible Text Books for Mathematics and Science Subjects of 8<sup>th</sup> Grade.

**Phase 2** - Screen Reader Accessibility Analysis of Mathematics & Science Text Books. Numbers of errors were noted while reading the text book while reading with Screen Readers such as JAWS, NVDA and TALKBACK.

Most common accessibility issues were i) Navigation issues, ii) inaccessible images, graphs, charts, iii) inaccessible mathematics equation, iv) Tables are not read properly, v) Special Character and QR codes irascibility.

**Phase 3** - Development of Accessible Text Book for Students with Visual Impairment. Mathematics and Science Text Books (Term 1) of 8<sup>th</sup> Grade were taken

for the study. 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:**

1. **Titles and subtitles** (i.e. sections and subsections) were marked with the appropriate tags. Heading levels were selected according to the nature of the heading.
2. **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.
3. **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.
4. **Image Description:** Images were tagged and an appropriate textual description that clearly explains the information provided were given to each images.
5. **Tables :** Tables were 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)
6. **Mathematics equation :** To enhance accessibility of Maths equations two ways were followed
  - i. Small equations were directly inserted in the text book
  - ii. Solution for Mathematics equations were created using Use Mathpix Snipping tool “Mathpix”

**5.2.2 Stage 2:** Comparison Study of Digital Text Book & Newly Developed Accessible Text Book on enhanced Accessibility features for Students with Visual Impairment.

### **5.2.2.1 Sample**

The samples for the study was selected from “Coimbatore District of Tamil Nadu”. The sample comprised of 60 people with visual impairment including 30 students with Visually Impaired Students and 30 Special Educators were selected for the study. Purposive Sampling Technique was used to select the sample.

### **5.2.2.2 Variables :**

Dependent Variables of the study were Over all Accessibility Features of Digital Text Book and Newly Developed Accessible text Books of Mathematics and Science subjects of 8<sup>th</sup> Grade validated by Students with Visual Impairment and Special Educators using Screen Readers. The independent variables are Screen readers such as NVDA, JAWS, TALKBACK.

Comparative study was conducted to analyze the accessibility features of Tamil Nadu Government Digital Text book of Mathematics and Newly Developed Accessible Text Book for Mathematics and Science subjects of 8<sup>th</sup> Grade.

### **5.2.2.3 Tools**

A rating scale consists of 20 questions assess the Accessibility Features of the Text Books 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

## **5.3 Data Collection Procedure**

### **Phase I:**

**Step 1:** Students with Visual Impairment were oriented to access Science and Mathematics Digital Text Books of 8<sup>th</sup> grade using 3 screen readers namely JAWS,NVDA and TALKBACK.

**Step 2:** Rating scale was administered to the students with Visual Impairment and the investigator interviewed the visually impaired students and got their rating for accessibility features of the Mathematics and Science digital text book while using different screen readers.

## **Phase II:**

**Step 1:** Special Educators were oriented to access Science and Mathematics Digital Text Books of 8<sup>th</sup> grade using 3 screen readers namely JAWS,NVDA and TALKBACK.

**Step 2:** Rating scale was administered to the Special Educators and filled the rating scale for accessibility features of the Mathematics and Science digital text book while using different screen readers.

## **Phase III:**

**Step 1:** Students with Visual Impairment were oriented to access Newly developed Accessible Text Books for Science and Mathematics subjects of 8<sup>th</sup> grade using 3 screen readers namely JAWS,NVDA and TALKBACK.

**Step 2:** Rating scale was administered to the students with Visual Impairment and the investigator interviewed the visually impaired students and got their rating for accessibility features of the Newly Developed Mathematics and Science text book while using different screen readers.

## **Phase IV:**

**Step 1:** Special Educators were oriented to access Newly developed Accessible Text Books for Science and Mathematics subjects of 8<sup>th</sup> grade using 3 screen readers namely JAWS,NVDA and TALKBACK.

**Step 2:** Rating scale was administered to the Special Educators and filled the rating scale for accessibility features of Newly Developed Accessible text Books for Mathematics and Science of 8<sup>th</sup> Grade while using different screen readers.

## **5.4. Major Findings**

### ***5.4.1 Results pertaining to Science Text Book***

1. On Comparing the Overall Accessibility Features by Students with Visual Impairment with Screen Readers namely NVDA, JAWS and TALKBACK the Newly Developed Science Accessible Text Book has better overall

accessibility features than the Digital Science Text Book (Digital Mean: 34.83, 35.70, 35.38 & Accessible Mean: 52.60, 52.63, 51.82).

2. Considering the five Components of accessibility the Students with Visual Impairment rated that the Newly Developed Accessible Science Text Book has better in all accessibility components than Digital Science Text Book with Screen Readers namely NVDA, JAWS and TALKBACK
  - i. **Text:** Accessible Mean: 13.07, 13.07, 12.80 & Digital Mean: 9.10, 9.90, 11.0.
  - ii. **Visual Representation:** Accessible Mean: 13.13, 13.53, 12.97 & Digital Mean: 8.30, 6.87, 6.83
  - iii. **Content formatting:** Accessible Mean: 10.80, 10.67, 10.57 & Digital Mean: 8.20, 8.20, 8.20.
  - iv. **Special characters:** Accessible Mean : 7.80, 7.53, 7.60 & Digital Mean : 4.03, 5.60, 4.50
  - v. **Accessible Support :** Accessible Mean: 7.80, 7.83, 7.80 & Digital Mean 5.20, 5.13, 5.00
3. The Special Educators rated that the Newly Developed Science Accessible Text Book (Mean: 53.33, 53.07, 51.93) was better than Digital Science Text Book (Mean: 34.93, 35.27, 34.73) in Overall Accessibility features with all three Screen Readers namely NVDA, JAWS and TALKBACK
4. Considering the five Components of accessibility the Special Educators rated that the Newly Developed Accessible Science Text Book has better in all accessibility components than Digital Science Text Book with Screen Readers namely NVDA, JAWS and TALKBACK
  - i. **Text:** Accessible Mean: 12.93, 13.13, 12.80 & Digital Mean: 9.53, 10.00, 11.00.
  - ii. **Visual Representation:** Accessible Mean: 113.33, 13.47, 12.97 & Digital Mean: 8.20, 6.73, 6.83
  - iii. **Content formatting:** Accessible Mean: 10.93, 11.00, 10.57 & Digital Mean: 8.20, 7.80, 8.20.

- iv. **Special characters:** Accessible Mean : 8.07, 7.73, 7.60 & Digital Mean : 4.00, 5.80, 4.50
- v. **Accessible Support :** Accessible Mean: 8.07, 7.73, 7.83 & Digital Mean : 5.00, 4.93, 5.17

#### ***5.4.2 Results Pertaining to Mathematics Text Book***

1. 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).
2. 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 Text Book 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
  - iii. **Content formatting:** Accessible Mean: 9.70, 9.77, 9.97 & Digital Mean 5.30, 5.30, 5.87
  - iv. **Special characters:** Accessible Mean : 7.10, 7.20, 7.27 & Digital Mean : 3.97, 4.07, 4.30
  - v. **Accessible Support :** Accessible Mean: 7.27, 7.10, 7.13 & Digital Mean 4.53, 4.37, 4.30 )
3. T-Test scores of Special educators rating with Screen Readers on Overall accessibility showed that the Newly Developed Mathematics Accessible Text book is better in all accessibility than Digital Mathematics Text Book [NVDA, JAWS and TALKBACK- (Digital Mean: 28.20, 27.23, 29.93 7 & Accessible mean:48.43, 48.10, 48.57).

4. 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 Text Book 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: 12.03, 11.67, 11.93 & Digital Mean: 7.00, 6.57, 7.33
  - iii. **Content formatting**: Accessible Mean: 9.80, 9.93, 9.97 & Digital Mean: 5.67, 5.33, 6.00
  - iv. **Special characters**: Accessible Mean : 7.23, 7.47, 7.43 & Digital Mean : 4.13, 3.87, 4.43
  - v. **Accessible Support** : Accessible Mean: 4.33, 4.20, 4.70 & Digital Mean 7.20, 7.23, 7.27.

### **5.5. Recommendations**

1. The newly developed Accessible text Book may be the prototype model for accessible Text Book Development
2. The methodology adopted for developing accessible text book would consider for make policy into practice of right to accessible materials
3. Government Digital Text Book for all subjects can be developed with accessibility
4. The study may suggest accessibility guidelines for Other Digital Book developers also

### **5.6. Limitation of the Study**

The limitations of the study are listed below:

1. The study focused only the Screen Reader Accessibility for Visually impaired
2. The study used only three Screen Readers
3. In this study Science and Mathematics digital Text Books only taken.

## **5.7. Conclusion**

Text book 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 up for students with visual impairment. The ready available electronic files of the textbooks can be read with screen readers. Accessible Text Books 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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**Avinashilingam Institute for Home Science and Higher Education for Women**  
(Deemed to be university under category 'A' by MHRD, Estd.u/s 3 of UGC act 1956)  
Re-accredited with 'A++' grade by NAAC)CGPA 3.65/4, Category I by UGC  
Coimbatore - 641043, Tamil Nadu, India.

### APPENDIX- I(A)

Name of the Participant :  
Age :  
Gender :  
Type of Disability :  
Education Qualification :



**Avinashilingam Institute for Home Science and Higher Education for Women**  
(Deemed to be university under category 'A' by MHRD, Estd.u/s 3 of UGC act 1956)  
Re-accredited with 'A++' grade by NAAC)CGPA 3.65/4, Category I by UGC  
Coimbatore - 641043, Tamil Nadu, India.

### **APPENDIX- I(B)**

Name of the Teacher :  
Age :  
Gender :  
Education Qualification :

## APPENDIX II

### RATING SCALE ON ACCESSIBILITY OF DIGITAL /ACCESSIBLE TEXT BOOK

S.No	Particulars	Completely accessible	Partially accessible	Inaccessible
I.	<b>Text</b>			
1.	All of the text that is displayed be read aloud by text-to-speech software			
2.	The text navigable with page to page			
3.	The text navigable with line to line			
4.	The equation are rendered in a correct format			
5.	Continue reading the line after pause/order of reading			
II.	<b>Visual Representation</b>			
6.	Alternative text available for all flow charts			
7.	Alternative text available for all images			
8.	Alternative text available for all diagrams			
9.	The description given for mind map			
10.	Tables are properly read with the column and row			
III.	<b>Content Formatting</b>			
11.	The bullet list is clearly mentioned			
12.	The Number list is clearly mentioned			
13.	The heading level is mentioned for different headings (lesson title, sub title)			
14.	The page number is clearly mention as in the Book			
IV.	<b>Special Characters</b>			
15.	The punctuation marks are mentioned clearly? For example:(“ ”Quotation, Apostrophe , : Colon , () Bracket, Dash _____ )			
16.	The roman letters are clearly mentioned			
17.	The symbols are clearly mentioned (Science, Maths any other)			
V.	<b>Accessible supports</b>			
18.	The magnifier (Zoom) option is available			
19.	The color contrast option is available			
20.	The QR code captioned with accessible link			

**APPENDIX- III (A)**  
**Accessible Science Text Book**  
**(Term -1: Lesson-1 “Measurement”)**

1

## Unit 1 - Measurement



*XDED2K*

**At the end of this lesson, students will be able to:**

- Understand SI units, base quantities and base units.
- Explain the system of units and measurements.
- Analyze the different system of units.
- Know about temperature, amount of substance, electric current and luminous intensity.
- Explore the knowledge of accuracy in measurements.
- Difference between the plane angle and solid angle, different clocks.
- Solve the numerical problems.

### **Introduction**

Physics is the study of nature and natural phenomena. Physics is considered as the base of all science subjects. Physics is based on experimental observations. The principles and observations allow us to develop a deeper understanding of nature. Scientific theories are valid, only if they are confirmed through various experiments.

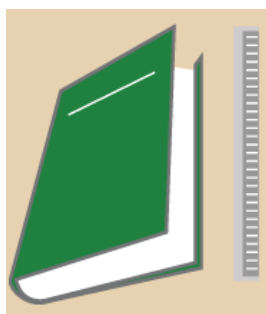
Theories in physics use many physical quantities that have to be measured.

Measurement is the base of all scientific studies and experimentations. It plays a vital role in our daily life. Measurement is the process of finding an unknown physical quantity by using a standard quantity.

We need three things for a perfect measurement. They are (i) an instrument, (ii) a standard quantity and (iii) an acceptable unit.

### **Activity 1**

Students are asked to measure the length and breadth of their science book using a ruler (scale) and compare their measurement with those of their friends.



In this activity, let the length of the book be 15 cm, the length is the physical quantity, ruler is the 'instrument', 15 is the 'magnitude' and 'cm' is the unit. This process is called "Measurement".

Here, all the students will not get the same value. Thus, one can infer that there may be an error while taking the measurement. This lesson helps us to get a better understanding of measurements.

### **1.1 - System of Units**

People in various part of the world are using different systems of units for measurement.

Some common systems of units are:

1. FPS - System (Foot for length, Pound for mass and Second for time)
2. CGS -System (Centimetre for length, Gram for mass and Second for time)
3. MKS - System (Metre for length, Kilogram for mass and Second for time)

#### **Do you know?**

The 'CGS', 'MKS' and SI units are metric systems of units and 'FPS' is not an metric system. It is a British system of units.

#### ***1.1.1 - International System of Units***

In earlier days, scientists performed their experiments and recorded their results in their own system. Due to lack of communication, they couldn't organize other's experimental results. So, the scientists planned to follow a uniform system for taking the measurements.

As you studied in the lower classes, in 1960, in the 11<sup>th</sup> General Conference on Weights and Measures at Paris in France, the scientists recognized the need of using standard units for physical quantities.

That was called as "International System of Units" and is popularly known as SI System (abbreviated from the French name 'Système International'). The scientists chose seven physical quantities as 'Base Quantities' and defined a 'Standard Unit' to measure each one.

They are known as Base Units or Fundamental Units (Table 1.1)

### 1.1.2 - SI Base Units

Table: 1.1 Base Quantities and Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Electric Current	ampere	A
Amount of Substance	mole	mol
Luminous Intensity	candela	cd

You have already studied about Length, Mass and Time in the lower classes. So, now you are going to study about the other base quantities such as temperature, current, amount of substance and luminous intensity.

#### Do you know?

In December 1998, the National Aeronautics and Space Administration (NASA), USA launched the Mars Climate Orbiter to collect the data of the Martian climate. Nine months later, on September 23, 1999, the Orbiter disappeared while approaching Mars at an unexpectedly low altitude. An investigation revealed that the orbital calculations were incorrect due to an error in the transfer of information between the spacecraft's team in Colorado and the mission navigation team in California. One team was using the English FPS system of units for calculation, while the other group was using the MKS system of units.

This misunderstanding caused a loss of approximately 125 million dollars.

### 1.2 - Temperature

Identify, which of these objects are hot or cold? (Fig 1.1)



Fig 1.1 - Various Hot and Cold Objects

You can see that some objects are cold, and some are hot. You also know that, some objects are hotter than others while some of them are colder than others.

How do you decide, which is hotter and which is colder? So, you need a reliable quantity to decide the degree of hotness or coldness of an object. That quantity is 'temperature'.

Temperature is a physical quantity that expresses the degree of hotness or coldness of a substance. Heat given to a substance will increase its temperature. Heat removed from a substance will lower its temperature.

### 1.2.1 - Definition

Temperature is a measure of the average kinetic energy of the particles in a system.

The SI unit of Temperature is kelvin. 'Thermometers' are used to measure temperature directly.

Usually, thermometers are calibrated with some standard scales. Celsius, Fahrenheit, Kelvin are the most commonly used scales to measure Temperature.

In these thermometers, melting point of pure ice ( $0^{\circ}\text{C}$ ) is taken as Lower Fixed Point (LFP) and Boiling point of water ( $100^{\circ}\text{C}$ ) is taken as Upper Fixed Point (UFP).

Table: 1.2 Various Scales to measure Temperature

Types of Scale	Lower Fixed Point (LFP)	Upper Fixed Point (UFP)	No. of divisions in thermometer
Celsius	$0^{\circ}\text{C}$	$100^{\circ}\text{C}$	100
Fahrenheit	$32^{\circ}\text{F}$	$212^{\circ}\text{F}$	180
Kelvin	273 K	373 K	100

## Activity 2

Measure the room temperature inside the class room and outside the class room by using a thermometer and tabulate it with different time intervals for a week. Do you find any differences in these values? Discuss your observations.

Day	10:00 a.m. Inside	10:00 a.m. Outside	12:00 p.m. Inside	12:00 p.m. Outside	2:00 p.m. Inside	2:00 p.m. Outside	4:00 p.m. Inside	4:00 p.m. Outside
Day-1								
Day-2								
Day-3								
Day-4								
Day-5								

### 1.2.2 - Conversion of Scales of Temperatures

The general formula for the conversion of scales of temperature is:

$$\frac{C - 0}{100} = \frac{F - 32}{180} = \frac{K - 273}{100}$$

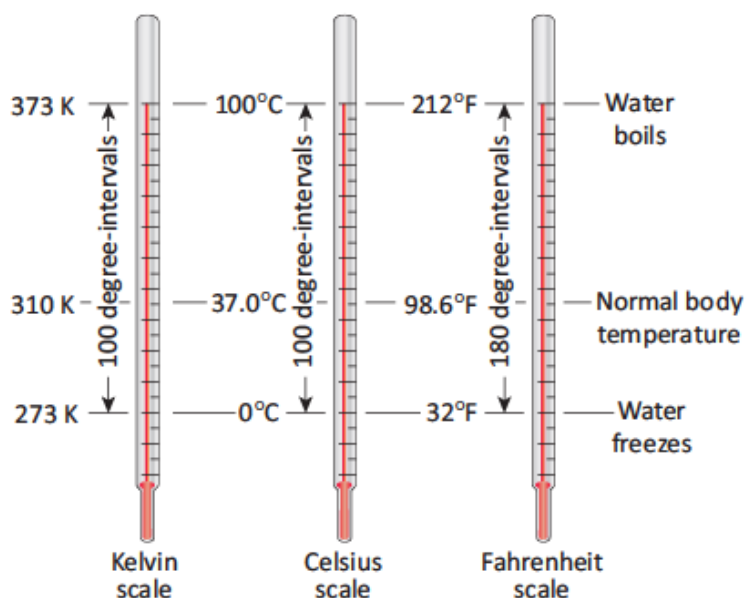


Fig: 1.2 - Various Thermometers

### 1.2.3 - Application of various thermometric scales

1. Physicians use 'clinical thermometers'. It is graduated in 'Fahrenheit Scale'
2. Scientists are using thermometers with kelvin scale.

3. Common temperature measurements are made in Celsius scale. (Example: Weather reports are given in Celsius scale.)

### Info bits

“Normal temperature of the human body is between 98.4°F and 98.6°F”

### Do you know?

Infra red thermometer, measures the temperature of an object without any physical contact.

### Activity 3

Collect the highest and lowest temperature details of your nearest town or city from the news paper or television for a week and record the values in a tabular column. Does this data remain same throughout the year?

### 1.3 - Electric Current (I)

Flow of electric charges, in a particular direction is known as ‘electric current’.

The magnitude of an electric current is the amount of electric charges flowing through a conductor in one second.

$$\text{Total capitalised value of the business} = \frac{\text{Average profit}}{\text{Normal rate of return}} \times 100$$

$$I = \frac{Q}{t}$$

SI unit of Electric Current is ‘ampere’ and it is denoted as A. Unit of charge is coulomb.

**One ampere** is defined as one ‘coulomb’ of charge moving in a conductor in one second. Ammeter is a device used to measure ‘electric current’. (Fig 1.3)



Fig 1.3 - Ammeter

### More to Know

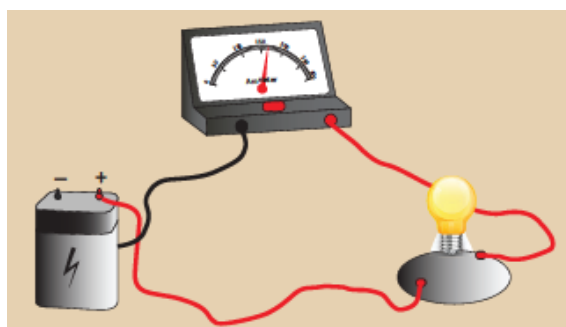
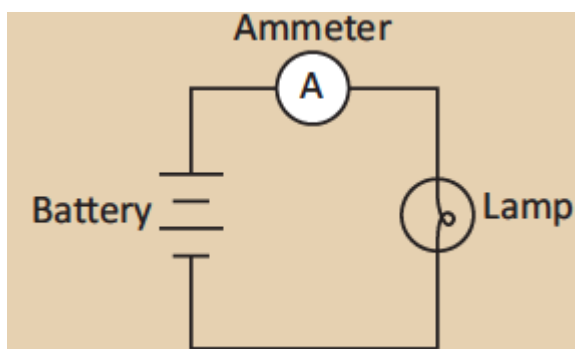
At very low temperature, around 30K ( $-243.2^{\circ}\text{C}$ ), some conductors conduct electric current without any loss. These conductors are known as 'SUPER CONDUCTORS'.

The super conductors are used to levitate trains from the track. Super conductors can be used as memory or storage element in the computers.



### Activity 4

Measure the current in an electric circuit.



**Components Required:** Battery, Ammeter, Lamp (Bulb)

#### Procedure:

1. Connect the battery, ammeter and the lamp in series as shown in the figure.
2. Note the ammeter reading
3. It is the current in the circuit

## 1.4 - Amount of substance



M6M2GC

Can you count the number of copper coins in the picture? (Fig 1.4)

Can you count the number of copper atoms in a coin? (Fig 1.4)

It is very difficult to count the number of atoms because the atoms are not visible. There is an indirect method to count the number of atoms or molecules in a substance in multiples of mole. Let us see in detail.



Fig 1.4 - Copper Coins

Amount of substance is a measure of the number of entities (particles) present in a substance. The entity may be an atom, molecule, ion, electron or proton etc.

Generally, the amount of substance is directly proportional to the number of atoms or molecules.

The SI unit of amount of substance is mole and it is denoted as 'mol'.

Mole is defined as the amount of substance, which contains  $6.023 \times 10^{23}$  entities.

### More to Know

The number  $6.023 \times 10^{23}$  is also known as Avogadro Number.

## 1.5 - Luminous Intensity



*Fig 1.5 (a & b) - Photometer in day to day life*

Have you seen these scenes on the television? (Fig 1.5)

What is the umpire doing? Is he taking a 'selfie'? (Fig 1.5)

No, he is checking the intensity of light, as perceived by the human eye, by using an instrument called 'Photometer'

### 1.5.1 - Definition

The measure of the power of the emitted light, by a light source in a particular direction, per unit solid angle is called as Luminous Intensity.

The SI unit of luminous intensity is candela and is denoted as 'cd'.



Fig 1.6 - Photometer

The light emitted from a common wax candle is approximately equal to one candela. Luminous intensity is measured by a 'photometer' (Fig 1.6) (Luminous Intensity Meter) which gives the luminous intensity in terms of candela directly.

#### Info bits

Luminous Flux or luminous power is the measure of the perceived power of light. Its SI unit is 'lumen'.

One lumen is defined as the luminous flux of the light produced by the light source that emits one candela of luminous intensity over a solid angle of one steradian.

### 1.6 - Plane angle

It is the angle between the intersection of two straight lines or intersection of two planes. (Fig 1.7) The SI unit of Plane Angle is 'radian' and is denoted as 'rad'.

Radian is the angle subtended at the centre of a circle by an arc whose length is equal to the radius of the circle. (Fig 1.8).

$$\pi \text{ radian} = 180^\circ$$

$$1 \text{ radian} = \frac{180^\circ}{\pi}$$

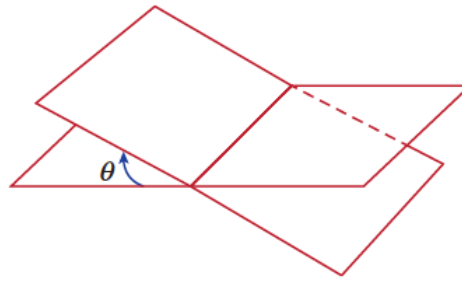


Fig 1.7 - Plane Angle

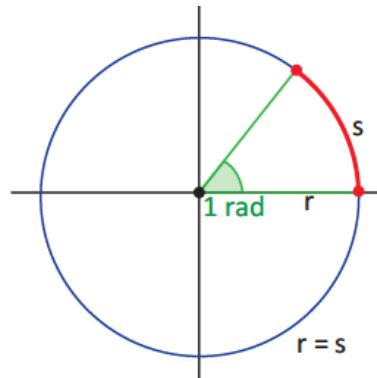


Fig 1.8 - Radian

## 1.7 - Solid Angle



Z38W68

Z38W68

It is the angle formed by three or more planes intersecting at a common point.

It can also be defined as 'angle formed at the vertex of the cone' The SI unit of solid angle is 'steradian' and is denoted as 'sr'.

### 1.7.1 - Definition

Steradian is the solid angle at the centre of a sphere subtended by a portion whose surface area is equal to the square of its radius of the sphere. (Fig 1.9)

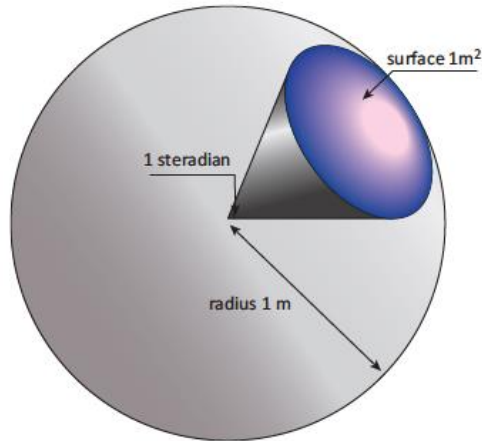


Fig 1.9 - Steradian

### Do you know?

Until 1995, Plane Angle and Solid Angle were classified under supplementary quantities. In 1995, they were shifted to derived quantities.

Table: 1.3 Difference between Plane Angle and Solid Angle

Plane Angle	Solid Angle
Angle between the intersection of two lines or planes	Angle between the intersection of three or more planes at a common point
It is two dimensional	It is three dimensional
Unit is radian	Unit is steradian

### 1.8 - Clocks

Clocks are used to measure time intervals. So, many clocks were used from the ancient time. Scientists modified the clock's mechanism to obtain accuracy.



Fig 1.10 - Ancient Clock

### 1.8.1 - Types of clocks based on display:

1. Analog clocks
2. Digital clocks

#### 1. Analog clocks



Fig 1.11 - Analog Clock

It looks like a classic clock. It has three hands to show the time. (Fig 1.11)

**Hours Hand:** It is short and thick. It shows 'hour'.

**Minutes Hand:** It is long and thin. It shows 'minute'.

**Seconds Hand:** It is long and very thin. It shows 'second'. It makes one rotation in one minute and 60 rotations in one hour.

Analog clocks can be driven either mechanically or electronically.

#### Activity 5

Students must make a model of an Analog clock using a cardboard.

#### 2. Digital clocks

A digital clock displays the time directly. It shows the time in numerals or other symbols. It may have a 12 hours or 24 hours display. (Fig 1.12) Recent clocks are showing Date, Day, Month, Year, Temperature etc. Digital clocks are often called as Electronic Clocks.



Fig 1.12 - Digital Clock

## Activity 6

Students must make a model of a digital clock using match sticks on a cardboard, with date and time.

### 1.8.2 - Types of clocks based on working mechanism

#### 1. Quartz Clock:

These clocks are activated by 'electronic oscillations', which are controlled by a 'quartz crystal'. (Fig 1.13)

The frequency of a vibrating crystal is very precise. So, the quartz clock is more accurate than the mechanical clock.

These clocks have an accuracy of one second in every  $10^9$  seconds.



Fig 1.13 - Quartz Clock

#### More to Know

The principle of a quartz clock is the Piezo - electric property of a crystal. Piezo-electric property means that when a pressure is applied along a particular axis of a crystal, an electric potential difference is developed in a perpendicular axis.

In the reverse piezo-electric effect, a crystal becomes mechanically stressed when a voltage is applied across its opposite faces.

#### 2. Atomic Clock:



BYUQV4

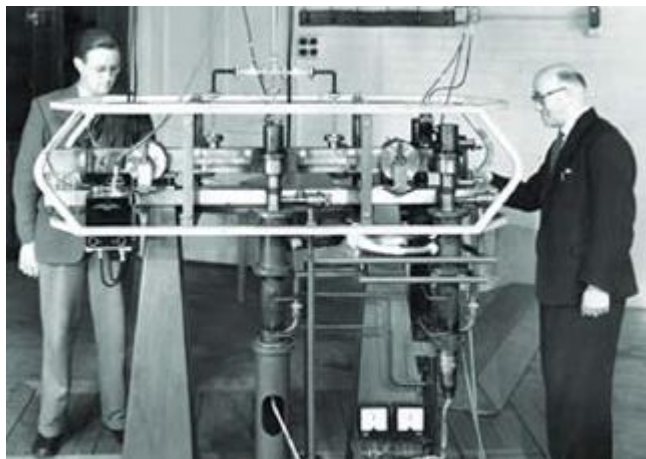
These clocks are making use of periodic vibrations occurring within the atom. (Fig 1.14)  
These clocks have an accuracy of one second in every  $10^{13}$  seconds.

Atomic clocks are used in Global Positioning System (GPS), Global Navigation Satellite System (GLONASS) and International time distribution services.

### More to Know

The first atomic clock was developed in 1949 at the US National Bureau of Standards. But, it was less accurate than the quartz clock.

The first accurate atomic clock (based on Caesium - 133) was built by Louis Essen and Jack Penny in 1955, at the National Physics Laboratory in the United Kingdom.



### Activity 7

You may know about the 'Sun Dial'. Construct a sundial of your own and read out the values from morning to evening. Compare your values with modern clocks.

### Do you know?

**Greenwich Mean Time (GMT)** is the mean solar time at the Royal Observatory, located at Greenwich in London. It is measured at the longitude of zero degree.

The Earth is divided into 24 zones, each of a width of 15 degree longitude. These regions are called as 'Time Zones'. Time difference between two adjacent time zones is 1 hour.

**Indian Standard Time (IST):** The location of Mirzapur in Uttar Pradesh is taken as the reference longitude of the Indian Standard Time. It is located at 82.5 degree longitude.

**IST = GMT + 5:30 hours**

### 1.9 - Accuracy in Measurements

Measurement is the base of all experiments in science and technology. The value of every measurement contains some uncertainty. These uncertainties are called as 'Errors'. The difference between the real value and the observed value is called an error.



Fig 1.15 - Accuracy and Precision

### 1.9.1 - Accuracy

Accuracy is the closeness of a measured value to the actual value or true value. (Fig 1.15)

### 1.9.2 - Precision

Precision is the closeness of two or more measurements to each other. (Fig 1.15)



NVGKJZ

## 1.10 - Approximation

### Activity 8

Observe the 'Rasam making' process in your home. Ask your elders and try to answer the following questions:

- The rasam is made for how many persons?
- How could you increase the taste?
- How much of salt has to be added?
- Is there any prescribed standard for taking the ingredients?

We are not following any standard values for preparing a dish. We are following an approximation method for choosing ingredients.

While we prepare a dish, the ingredients are taken approximately.

Approximation is the process of finding a number, which is acceptably close to the exact value of the measurement of a physical quantity.

It is an estimation of a number obtained by rounding off a number to its nearest place value.

When the data are inadequate, physicists are in need of an approximation to find the solution for problems. Approximations are usually based on certain assumptions having a scientific background and they can be modified whenever accuracy is needed.

### **Activity 8**

Calculate the approximate 'heart beat' of a man in a day. (Hint: Take number of heart beats per minute as 75, approximately)

#### **1.11 - Rounding off**

Calculators are widely used in day to day life to do the calculations. The result given by a calculator has too many digits. Hence, the result containing more digits should be rounded off. The technique of rounding off is used in many areas of physics.

##### **1.11.1 - Rules for rounding off**

- Decide which is the last digit to keep.
- Leave it the same, if the next digit is less than 5.
- Increase it by one, if the next digit is 5 or greater than 5.

#### **Thinking Corner:**

Since, the true value is also an observed value then what is meant by true value? Think and discuss it with your friends?

#### **1.12 - Numerical Problems:**

1. Convert 80°C into kelvin.

**Solution:**

$$K = C + 273$$

$$K = 80 + 273$$

$$K = 353 \text{ kelvin}$$

2. Convert 300 K into Celsius.

**Solution:**

$$C = K - 273$$

$$C = 300 - 273$$

$$C = 27 \text{ celsius.}$$

3. When 2 coulomb of charge, flows through a circuit for 10 seconds, calculate the current?

**Solution:**

Given: Charge  $Q = 2C$ ; time  $t = 10s$

$$I = \frac{Q}{t} \text{ or } I = \frac{2}{10}$$

$$I = 0.2A$$

4. Convert  $60^\circ$  into radian.

$$1^\circ = \frac{\pi}{180}$$

$$60^\circ = \frac{\pi}{180} \times 60$$

$$= \frac{\pi}{3} \text{ radian}$$

5. Convert  $\frac{\pi}{4}$  into degrees.

$$\pi \text{ radian} = 180^\circ$$

$$\frac{\pi}{4} \text{ radian} = \frac{180}{4} = 45^\circ$$

6. Round off the number 1.864 to two decimal places

**Step: 1:** Identify the last digit to be kept. 6 is the last digit to be kept.

**Step: 2:** The following digit, i.e. 4 is less than 5. So, retain it as 6. The answer is 1.86

7. Round off the number 1.868 to two decimal places

**Step: 1** Identify the last digit to be kept. 6 is the last digit to be kept.

**Step: 2** The following digit, i.e. 8 is greater than 5. So, increase 6 by one. The answer is 1.87

**APPENDIX- III (B)**  
**Accessible Mathematics Text Book**  
**(Term -1: Lesson-1 “Rational Numbers”)**

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**1 - Rational Numbers**

**Learning Outcomes**

- To understand the necessity for extending fractions to rational numbers.
- To represent rational numbers on the number line.
- To understand that between any two given rational numbers, there lies many rational numbers.
- To learn and perform the four basic operations on rational numbers.
- To solve the word problems on all the operations.
- To understand the properties, the additive identity and inverse and the multiplicative identity and inverse of rational numbers.
- To know how to simplify expressions with at most three brackets.



*B7XMD8*

**1.1 - Introduction**

**Think about the situation**

**Observe the following conversation:**

Pari: My dear friend Sethu, I have a doubt about fractions on the number line. Can you please clear that doubt?

Sethu: Tell me Pari, I will be happy to help you.

Pari: We know about fractions, right? Fractions like  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{2}{3}$ ,  $\frac{3}{4}$  are obviously clear, that  $\frac{1}{4}$  represents 1 out of 4 parts,  $\frac{1}{2}$  is 1 out of 2 parts and so on. But, where are they on the number line?

Sethu: Pari, it is easy to identify where they are on the number line. The fractions you have given here are proper fractions. Aren't they? As we know, proper fractions are greater than zero but definitely less than one.

Pari: Yes, I do agree to that, Sethu.

Sethu: Now, let me tell you where they lie on the number line. See the line that I have drawn for you.

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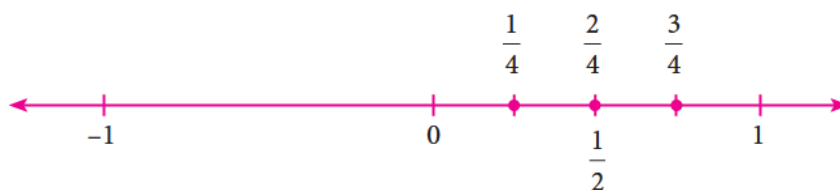


Fig 1.1

As you see here Pari,  $\frac{1}{2}$  is exactly at the middle of 0 and 1 whereas  $\frac{1}{4}$  is exactly at the middle of 0 and  $\frac{1}{2}$ . Also  $\frac{3}{4}$  is exactly at the middle of  $\frac{1}{2}$  and 1. Also, when we divide the distance between 0 and 1 roughly into 3 equal parts, the second part of it, represents  $\frac{2}{3}$ . Is it clear now?

Pari: Fine, it is very clear now. I think that these fractions,  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{3}{4}$ , and also correspond to the decimals 0.25, 0.50, 0.75 and 0.66. Am I correct, Sethu?

Sethu: Yes, you are correct.

Pari: By the way, I think that the improper fractions,  $\frac{13}{5}$ ,  $\frac{10}{3}$ ,  $\frac{31}{7}$ , etc., should be converted into mixed fractions as  $2\frac{3}{5}$ ,  $3\frac{1}{3}$ ,  $4\frac{3}{7}$ , respectively, so as to locate them easily on the number line as given below.

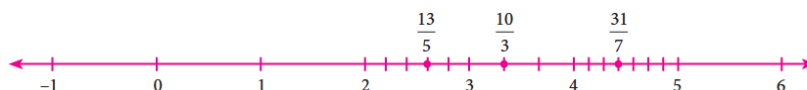


Fig 1.2

Sethu: Yes Pari, you are right. Here, it is clear that  $\frac{13}{5}$  lies between 2 and 3,  $\frac{10}{3}$  lies between 3 and 4 whereas  $\frac{31}{7}$  lies between 4 and 5.

Pari: Sethu, let me ask you another question. If 50 students in a class contribute equally to a total of ₹ 35 for a cause, how much does each one contribute?

Sethu: It is simple. Each one's contribution is  $\frac{35}{50}$ , simplified to  $\frac{7}{10}$  of a rupee, which is 70 paise (or) ₹ 0.70. Why do you ask this question here, Pari?

Pari: Wait Sethu. Tell me, what if they (50 students) have a debt of ₹ 35? Shall I denote it by a negative sign as  $-\frac{7}{10}$ ?

Sethu: I also think so! As we have seen the extension of whole numbers to integers, these negative fractions need to be accommodated somewhere on the number line.

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Teacher: Pari and Sethu, I have been listening to your conversation for a while now. You have almost got everything correct! Now, we know that 0 acts as the mirror to the natural numbers (right of 0) to reflect negative integers (left of 0). By the same way, we can indicate the negative fractions on to the left of 0.

Sethu: Thank you, Teacher. We have now understood what you said and know how to mark negative fractions on the number line as under.

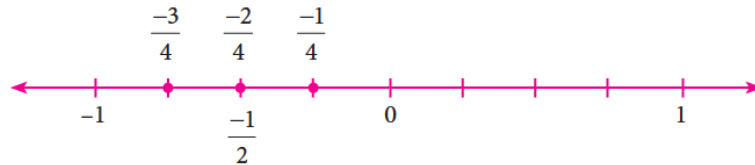


Fig 1.3

Observing the above conversation, one can see the need of negative fractions coming into the system of numbers that we have already know about.

**Recap**

Now let us recall about **Fractions**

- Write the following fractions in the appropriate boxes.

$\frac{-4}{5}, \frac{6}{7}, \frac{8}{3}, 4\frac{2}{3}, \frac{10}{7}, \frac{9}{12}, \frac{-12}{17}, 1\frac{4}{5}$

Proper fraction	Improper fraction	Mixed fraction	Negative Fraction

- Which of the following is not an equivalent fraction of  $\frac{8}{12}$ ?
  - $\frac{2}{3}$
  - $\frac{16}{24}$
  - $\frac{32}{60}$
  - $\frac{24}{36}$
- The simplest form of  $\frac{125}{200}$  is \_\_\_\_.
- Which is bigger  $\frac{4}{5}$  or  $\frac{8}{9}$ ?
- Add the fractions:  $\frac{3}{5} + \frac{5}{8} + \frac{7}{10}$
- Simplify:  $\frac{1}{8} - \left(\frac{1}{6} - \frac{1}{4}\right)$
- Multiply  $2\frac{3}{5}$  and  $1\frac{4}{7}$ .
- Divide  $\frac{7}{36}$  by  $\frac{35}{81}$ .

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9. Fill in the boxes:  $\frac{\quad}{66} = \frac{70}{\quad} = \frac{28}{44} = \frac{\quad}{121} = \frac{7}{\quad}$

10. In a city,  $\frac{7}{20}$  of the population are women and  $\frac{1}{4}$  are children. Find the fraction of the population of men.

### 1.1.1 – Necessity For Extending Fractions To Rational Numbers

For the easy understanding and mathematical clarity, we shall introduce the rational numbers abstractly by focusing on two properties, namely every number has an opposite and every non-zero number has a reciprocal.

- (i) Firstly, take the integers and form all possible 'fractions' where the numerators are integers and the denominators are non-zero integers. In this method, a rational number is defined as a 'ratio' of integers. The collection of rational numbers defined in this way will include the opposites of the fractions.
- (ii) Secondly, we could take all the fractions together with their opposites. This would give us a new collection of numbers, called the fractions and numbers such as  $\frac{-3}{4}$ ,  $\frac{5}{-9}$ ,  $\frac{-13}{2}$ , etc.,

We know that, the fraction  $\frac{4}{5}$  satisfies the equation  $5x = 4$  since  $5 \times \frac{4}{5} = 4$  and  $-2$  satisfies the equation  $x + 2 = 0$ , since  $-2 + 2 = 0$ . However, there is neither a fraction nor an integer that satisfies the equation  $5x + 2 = 0$ .

We have studied about integers. We you add, subtract or multiply two or more integers, you will get only an integer. If we divide two integers, we will not always get an integer. For example,  $\frac{-3}{5}$  and  $\frac{-4}{-8}$  are not integers. These situations can be handled by extending the numbers to another collection of numbers called as rational numbers.

The following figure shows how rational numbers are an extension of the fractions and the integers.

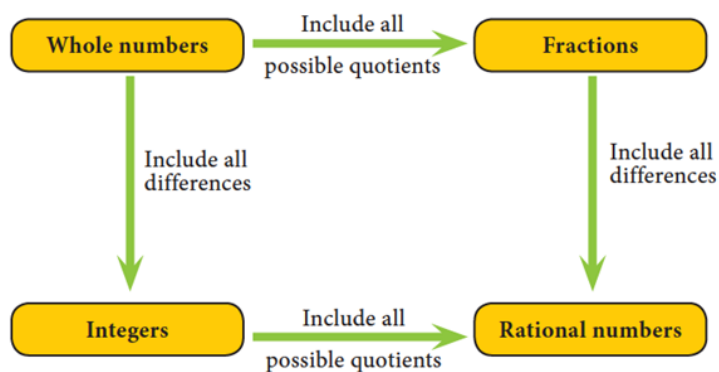


Fig 1.4

“image description begins:

The 4 interlinked options given in the image are as below:

Whole numbers  $\xrightarrow{\text{Include all possible quotients}}$  Fractions  $\xrightarrow{\text{Include all differences}}$  Rational Numbers

Whole numbers  $\xrightarrow{\text{Include all differences}}$  Integers  $\xrightarrow{\text{Include all possible quotients}}$  Rational Numbers.

Image description ends”

### MATHEMATICS ALIVE



If an orange is peeled off and 8 carpels are found, then one part of it represents the rational number  $\frac{1}{8}$ .

### RATIONAL NUMBERS IN REAL LIFE



An LPG domestic cylinder showing the weight of the tare and gas in decimal form.

## 1.2 - Rational Numbers - Definition

The collection of all numbers that can be written in the form  $\frac{a}{b}$ , where  $a$  and  $b$  are integers and  $b \neq 0$  is called rational numbers which is denoted by the letter Q. Here, the top number  $a$  is called the numerator and the bottom number  $b$  is called the denominator.

### Examples:

$\frac{1}{3}$ ,  $\frac{6}{11}$ ,  $\frac{-3}{5}$  and  $\frac{-11}{-25}$  are some examples of rational numbers. Also, integers like 7, -4 and 0 are rational numbers as they can be written in the form  $\frac{7}{1}$ ,  $\frac{-4}{1}$ , and  $\frac{0}{1}$ . Mixed numbers such as  $-4\frac{2}{5} = \frac{-22}{5}$ ,  $-5\frac{1}{3} = \frac{-16}{3}$ ,  $3\frac{1}{2} = \frac{7}{2}$  etc., are also rational numbers. So, all integers as well as fractions are rational numbers. The decimal numbers too, like 0.75, 1.3, 0.888 etc., are also rational numbers since they can be written in fractions form as:

$$0.75 = \frac{75}{100} = \frac{3}{4}$$

$$1.3 = \frac{13}{10} \text{ and}$$

$$0.888 = \frac{888}{1000} = \frac{222}{250} = \frac{111}{125}$$

In banks, home loans are given for a pre-determined interest rate as given above in decimal percentages which can be converted into rational numbers.

### Matters of Interest

- SBI's home loan rate for borrowers other than women for loans up to ₹30 lakh now 8.4%; for loans over ₹30 lakh, 8.55%.

- ICICI Bank charges 8.7% on home loans up to ₹75 lakh for salaried borrowers.
- HDFC charges between 8.5% and 9% for home loans up to ₹75 lakh.

### Note

The word 'ratio' in math refers to comparison of the sizes of two different quantities of any kind. For example, if there is one teacher for every 20 students in a class, then the ratio of teachers to students is 1:20. Ratios are often written as fractions and so  $1:20 = \frac{1}{20}$ . For this reason, numbers in the fractions form are called rational numbers.

### Try these

- Is the number  $\frac{7}{-5}$  a fraction or a rational number? Why?
- Write any 6 rational numbers of your choice.

### Activity-1

Use a string as a number line and fix it on the wall, for the length of the class room. Just mark the integers spaciouly and ask the students to pick the rational number cards from a box and fix it at the right place on the number line string. This can be played between teams and the team which fixes more number of cards correctly (by marking) will be the winner.



#### 1.2.1 - Rational Numbers On A Number Line

We know how the integers are represented on a number line. The same way, rational numbers can also be represented on a number line.

Now, let us represent the number  $\frac{-3}{4}$  on the number line. Being negative,  $\frac{-3}{4}$  would be marked to the left of 0 and it is between 0 and  $-1$ .

We know that in integers, 1 and  $-1$  are equidistant from 0 and so are the pairs 2 and  $-2$ , 3 and  $-3$  from 0. This remains the same for rational numbers too. Now, as we mark  $\frac{3}{4}$  to the right of zero, at 3 parts out of 4 between 0 and 1, the same way, we mark  $\frac{-3}{4}$  to the left of zero, at 3 parts out of 4 between 0 and  $-1$  as shown below.

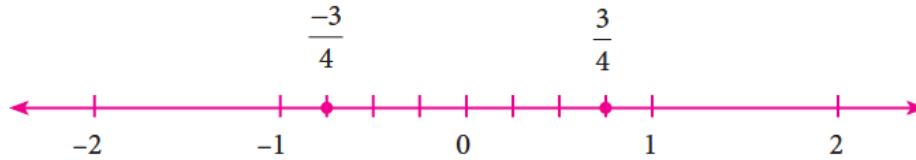


Fig. 1.5

Similarly, it is easy to say that  $\frac{-5}{2}$  lies between  $-2$  and  $-3$  as  $\frac{-5}{2} = -2\frac{1}{2}$ .

Remember that all proper rational numbers lie between  $0$  and  $1$  (or)  $0$  and  $-1$  just like the fractions.

Now, where do these rational numbers  $\frac{18}{5}$  and  $-\frac{32}{7}$  lie on a number line?

Here,  $\frac{18}{5} = 3\frac{3}{5}$  and  $-\frac{32}{7} = -4\frac{4}{7}$

Now,  $\frac{18}{5}$  lies between  $3$  and  $4$  on the number line. The unit part between  $3$  and  $4$  is divided into  $5$  equal parts and the third part is marked as  $\frac{3}{5}$ . Thus, the arrow mark indicates  $3\frac{3}{5} = \frac{18}{5}$ . Also, it is clear that the rational number  $-\frac{32}{7}$ , which is  $-4\frac{4}{7}$ , lies between  $-4$  and  $-5$  on the number line. Here, the unit part between  $-4$  and  $-5$  is divided to  $7$  equal parts and fourth part is marked as  $\frac{4}{7}$ . Thus the arrow mark indicates  $-4\frac{4}{7} = -\frac{32}{7}$ . These rational numbers are shown on the number line as shown below.

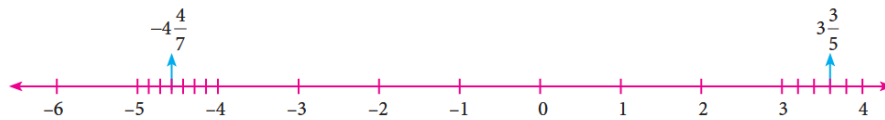


Fig. 1.6

### 1.2.2 - Writing A Decimal As A Rational Number

Every terminating or repeating decimal can be written in the rational form as shown in the following example.

#### Example 1.1

Write the following decimal numbers as rationals.

- (i) 3.0
- (ii) 0.25
- (iii) 0.666...
- (iv)  $-5.8$
- (v) 1.15

**Solution:**

- (i)  $3.0 = \frac{30}{10} = \frac{3}{1}$   
 (ii)  $0.25 = \frac{25}{100} = \frac{1}{4}$   
 (iii)  $0.666 \dots = \frac{2}{3}$  (check... you will know how in IX std)  
 (iv)  $-5.8 = \frac{-58}{10} = \frac{-29}{5} = -5\frac{4}{5}$   
 (v)  $1.15 = \frac{115}{100} = \frac{23}{20} = 1\frac{3}{20}$

**Note**

There are decimal numbers which are non-terminating and non-repeating, such as  $\pi = 3.1415926535\dots$ ,  $3.01002000400005\dots$  etc., They are not rational numbers because they cannot be written in  $\frac{a}{b}$  form.

**Try this**

Explain why the following statements are true?

- (i)  $0.8 = \frac{4}{5}$   
 (ii)  $1.4 > \frac{1}{4}$   
 (iii)  $0.74 < \frac{3}{4}$   
 (iv)  $0.4 > 0.386$   
 (v)  $0.096 < 0.24$   
 (vi)  $0.128 = 0.1280$

**1.2.3 - Equivalent Rational Numbers**

If the numerator and denominator of a rational number (say  $\frac{a}{b}$ ) is multiplied by a non-zero integer (say  $c$ ), we obtain another rational number which is equivalent to the given rational number. This is exactly the same way of getting equivalent fractions.

For example, take  $\frac{a}{b} = \frac{-4}{7}$  and  $c = 5$

Now,  $\frac{a}{b} \times \frac{c}{c} = \frac{a \times c}{b \times c} = \frac{-4 \times 5}{7 \times 5} = \frac{-20}{35}$  is an equivalent rational number to  $\frac{-4}{7}$  and if  $c$  is taken as 2, 3, -4 etc., the corresponding rational numbers are  $\frac{-8}{14}$ ,  $\frac{-12}{21}$ ,  $\frac{6}{-28}$  respectively.

**1.2.4 - Rational Numbers In Standard Form**

If in a rational number  $\frac{a}{b}$ , the only common factor of  $a$  and  $b$  is 1 and  $b$  is positive, then the rational number is said to be in standard form.

The rational numbers  $\frac{4}{5}$ ,  $\frac{-3}{7}$ ,  $\frac{1}{6}$ ,  $\frac{-4}{13}$ ,  $\frac{-50}{51}$  etc., are all said to be in standard form. If a rational number is not in the standard form, then it can be simplified to get the standard form.

**Note**

The quotient of two numbers with different signs is a negative number.

That is,  $\frac{-4}{5} = -\frac{4}{5}$  and  $\frac{4}{-5} = -\frac{4}{5}$  and so  $\frac{-4}{5} = \frac{4}{-5} = -\frac{4}{5}$

Also, if the two numbers are of the same sign, then the quotient is a positive number.

That is,  $\frac{+3}{+4} = \frac{3}{4}$  and  $\frac{-3}{-4} = \frac{3}{4}$ .

0 is neither a positive nor a negative rational number.

**DO YOU KNOW?****FD 2018 Interest Rates***Regular*

Min Rate	4.2%
Max Rate	6.5%

*Senior Citizen*

Min Rate	4.7%
Max Rate	7%

The collection of rational numbers is denoted by the letter Q because it is formed by considering all quotients, except those involving division by 0. Decimal numbers can be put in quotient form and hence they are also rational numbers.

**Example - 1.2**

Reduce to the standard form

- (i)  $\frac{48}{-84}$   
 (ii)  $\frac{-18}{-42}$

**Solution:**

- (i) **Method 1:**

$$\frac{48}{-84} = \frac{48 \div (-2)}{-84 \div (-2)} = \frac{-24 \div 2}{42 \div 2} = \frac{-12 \div 3}{21 \div 3} = \frac{-4}{7} \text{ (dividing by } -2, 2 \text{ and } 3 \text{ successively)}$$

**Method 2:** The HCF of 48 and 84 is 12 (Find it). Thus, we can get its standard form by dividing it by -12.

$$= \frac{48 \div (-12)}{-84 \div (-12)} = \frac{-4}{7}$$

- (ii) **Method 1:**

$$\frac{-18}{-42} = \frac{-18 \div (-2)}{-42 \div (-2)} = \frac{9 \div 3}{21 \div 3} = \frac{3}{7} \text{ (dividing by } -2 \text{ and } 3 \text{ successively)}$$

**Method 2:**

The HCF of 18 and 42 is 6 (Find it). Thus, we can get its standard form by dividing it by 6.

$$\frac{-18}{-42} = \frac{-18 \times (-1)}{-42 \times (-1)} = \frac{18}{42} = \frac{18 \div 6}{42 \div 6} = \frac{3}{7}$$

**Try these**

- Which of the following pairs represents equivalent rational numbers?

(i)  $\frac{-6}{4}, \frac{18}{-12}$

(ii)  $\frac{-4}{-20}, \frac{1}{-5}$

(iii)  $\frac{-12}{-17}, \frac{60}{85}$

- Find the standard form of

(i)  $\frac{36}{-96}$

(ii)  $\frac{-56}{-72}$

(iii)  $\frac{27}{18}$

- Mark the following rational numbers on a number line.

(i)  $\frac{-2}{3}$

(ii)  $\frac{-8}{-5}$

(iii)  $\frac{5}{-4}$

**1.2.5 - Comparison Of Rational Numbers**

You know how to compare integers and fractions taking two at a time and say which is smaller or greater. Now you will learn how to compare a pair of rational numbers.

- Two positive rational numbers, say  $\frac{3}{5}$  and  $\frac{5}{6}$  can be compared as studied earlier in comparison of two fractions.

- Two negative rational numbers, say  $\frac{-1}{2}$  and  $\frac{-4}{5}$  can be compared as follows.

Find the LCM of the denominators 2 and 5. Mark these rational numbers on a number line by finding their equivalent rational numbers having common denominator. Now, the equivalent rational numbers having the LCM 10 as common denominator are found as,

$$\frac{-1}{2} \times \frac{5}{5} = \frac{-5}{10} \text{ and } \frac{-4}{5} \times \frac{2}{2} = \frac{-8}{10}$$

We know that  $4 < 8$  and so  $-4 > -8$

$$\therefore \frac{-8}{10} < \frac{-5}{10}. \text{ Thus } \frac{-4}{5} < \frac{-1}{2}.$$

- If one of the two rational numbers is negative, say  $\frac{3}{8}$  and  $\frac{-2}{3}$ , we can easily say that  $\frac{3}{8} > \frac{-2}{3}$  (or)  $\frac{-2}{3} < \frac{3}{8}$  because we know that a positive number is always greater than a negative number.

**Example - 1.3**

Find which rational number is greater?

(i)  $\frac{5}{-4}, \frac{-11}{-7}$

(ii)  $\frac{-10}{3}, \frac{14}{-5}$

**Solution:**

(i) Now,  $\frac{5}{-4} = \frac{5 \times (-1)}{-4 \times (-1)} = \frac{-5}{4}$

Also  $\frac{-11}{-7} = \frac{-11 \times (-1)}{-7 \times (-1)} = \frac{11}{7}$

Here  $\frac{11}{7}$  is positive and  $\frac{-5}{4}$  is a negative rational number.

$\therefore \frac{11}{7} > \frac{-5}{4}$ , that is  $\frac{-11}{-7} > \frac{5}{-4}$

(ii) First, make the denominator of the rational number  $\frac{14}{-5}$  to be positive as  $\frac{-14}{5}$ .

Then, make the denominators the same by finding the LCM of the denominators.

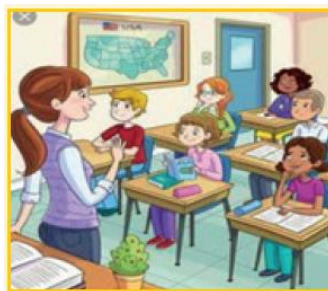
So,  $\frac{-10}{3} = \frac{-10}{3} \times \frac{5}{5} = \frac{-50}{15}$  and  $\frac{-14}{5} = \frac{-14}{5} \times \frac{3}{3} = \frac{-42}{15}$

As  $50 > 42$  we have  $-50 < -42$ .

Hence  $\frac{-50}{15} < \frac{-42}{15}$  and so  $\frac{-42}{15} > \frac{-50}{15}$ . Thus,  $\frac{14}{-5} > \frac{-10}{3}$ .

### Activity-2

Compare many rational numbers using the class room situations like the number of boys or girls to the total number of students, their test marks etc., to say which rational number is bigger or smaller?



### Example - 1.4

Write the following rational numbers in descending and ascending order.

$\frac{-3}{5}, \frac{7}{-10}, \frac{-15}{20}, \frac{14}{-30}, \frac{-8}{15}$

**Solution**

First make the denominators positive and write the numbers in standard form as  $\frac{-3}{5}, \frac{-7}{10}, \frac{-15}{20}, \frac{-14}{30}, \frac{-8}{15}$ . Now the LCM of 5,10,15,20 and 30 is 60 (How?). Change the given rational numbers to their equivalent form with common denominator 60.

$$\frac{-3}{5} = \frac{-3}{5} \times \frac{12}{12} = \frac{-36}{60}$$

$$\frac{7}{-10} = \frac{-7}{10} \times \frac{6}{6} = \frac{-42}{60}$$

$$\frac{-15}{20} = \frac{-15}{20} \times \frac{3}{3} = \frac{-45}{60}$$

$$\frac{-14}{30} = \frac{-14}{30} \times \frac{2}{2} = \frac{-28}{60}$$

$$\frac{-8}{15} = \frac{-8}{15} \times \frac{4}{4} = \frac{-32}{60}$$

Now, comparing the numerators  $-36, -42, -45, -28$  and  $-32$  we see that

$$-28 > -32 > -36 > -42 > -45$$

That is,  $\frac{-28}{60} > \frac{-32}{60} > \frac{-36}{60} > \frac{-42}{60} > \frac{-45}{60}$

and so,  $\frac{14}{-30} > \frac{-8}{15} > \frac{-3}{5} > \frac{7}{-10} > \frac{-15}{20}$

Hence, the descending order of the given rational numbers is  $\frac{14}{-30}, \frac{-8}{15}, \frac{-3}{5}, \frac{7}{-10}$  and  $\frac{-15}{20}$  and its reverse order gives the ascending order. Hence the ascending order of the given rational  $\frac{-15}{20}, \frac{7}{-10}, \frac{-3}{5}, \frac{-8}{15}$ , and  $\frac{14}{-30}$ .

### 1.2.6 - Rational Numbers Between Any Two Given Rational Numbers

**Think about the situation:**

Seyyon wanted to know the number of integers between  $-10$  and  $20$ . He found that there are 9 negative integers, zero and 19 positive integers, a total of 29 integers between  $-10$  and  $20$  (excluding  $-10$  and  $20$ ). He also finds that there is no other integer between any two consecutive integers.

Is this true for rational numbers too?

Seyyon took two rational numbers  $\frac{-3}{4}$  and  $\frac{-2}{5}$ . He converted them to rational numbers having the same denominators (find the LCM of the denominators).

So,  $\frac{-3}{4} = \frac{-3}{4} \times \frac{5}{5} = \frac{-15}{20}$

and  $\frac{-2}{5} = \frac{-2}{5} \times \frac{4}{4} = \frac{-8}{20}$

He could find rational numbers  $\frac{-9}{20}, \frac{-10}{20}, \frac{-11}{20}, \frac{-12}{20}, \frac{-13}{20}$  and  $\frac{-14}{20}$  between  $\frac{-8}{20}$  and  $\frac{-15}{20}$  but Seyyon doubts... Are these the only rational numbers between  $\frac{-15}{20}$  and  $\frac{-8}{20}$ ?

No, if we get the multiples of the denominator, then we can insert as many rational numbers as we want between any two given rational numbers.

For example,

$$\frac{-3}{4} = \frac{-15}{20} = \frac{-30}{40} \text{ and } \frac{-2}{5} = \frac{-8}{20} = \frac{-16}{40}$$

Now, between  $\frac{-30}{40}$  and  $\frac{-16}{40}$ , we could easily find as many as 13 rational numbers like  $\frac{-29}{40}$ ,  $\frac{-28}{40}$ , ...,  $\frac{-17}{40}$ .

Let us find more rational numbers say between  $\frac{3}{7}$  and  $\frac{4}{7}$ . This is clearly understood in the following visual explanation on the number line. We shall write  $\frac{3}{7}$  as  $\frac{30}{70}$  and  $\frac{4}{7}$  as  $\frac{40}{70}$ . Now, we see that there are 9 rational numbers between  $\frac{3}{7}$  and  $\frac{4}{7}$  as given in the number line below.

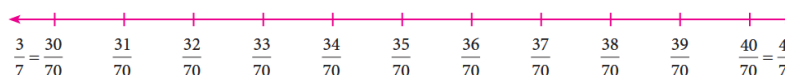


Fig. 1.7

Now, if we want more rational numbers between say  $\frac{37}{70}$  and  $\frac{38}{70}$  we can write  $\frac{37}{70}$  as  $\frac{370}{700}$  and  $\frac{38}{70}$  as  $\frac{380}{700}$ . Then again, we will get nine rational numbers between  $\frac{37}{70}$  and  $\frac{38}{70}$  as  $\frac{371}{700}$ ,  $\frac{372}{700}$ ,  $\frac{373}{700}$ ,  $\frac{374}{700}$ ,  $\frac{375}{700}$ ,  $\frac{376}{700}$ ,  $\frac{377}{700}$ ,  $\frac{378}{700}$  and  $\frac{379}{700}$ .

The following diagram helps us to understand this nicely with a magnifying lens used between 0 and 1 and further zoomed into the fractional parts also.

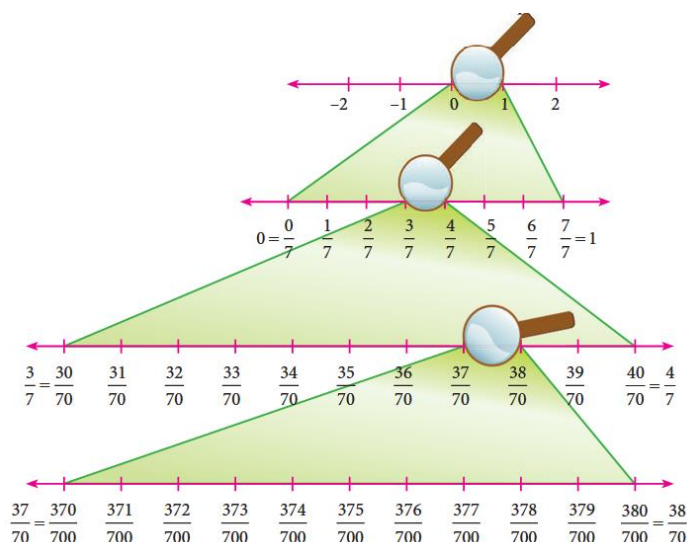


Fig. 1.8

Now, Seyyon understands that he can find an unlimited bunch of rational numbers between any two given rational numbers.

### 1.2.7 - Alternative Method For Finding Rational Numbers Between Any Two Rational Numbers By Average Concept.

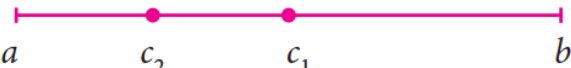
In this method, we shall use the average concept.

The average of two numbers  $a$  and  $b$  is  $\frac{1}{2}(a + b)$ .

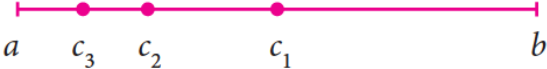
Let  $a$  and  $b$  any two given rational numbers. By using the average, we can find many rational numbers between  $a$  and  $b$  as  $c_1, c_2, c_3, c_4, c_5$  etc., as explained in the following.

$$c_1 = \frac{1}{2}(a + b)$$


The diagram shows a horizontal pink line segment with vertical tick marks at the ends labeled 'a' and 'b'. A single pink dot is placed at the midpoint of the segment, labeled 'c1' below it.

$$c_2 = \frac{1}{2}(a + c_1)$$


The diagram shows a horizontal pink line segment from 'a' to 'b'. There are two pink dots: one at the midpoint labeled 'c1' and another to its left labeled 'c2'.

$$c_3 = \frac{1}{2}(a + c_2)$$


The diagram shows a horizontal pink line segment from 'a' to 'b'. There are three pink dots: 'c1' at the midpoint, 'c2' to its left, and 'c3' to the left of 'c2'.

The numbers  $c_2, c_3$  are to the left of  $c_1$ . Similarly, we have  $c_4, c_5$  on the right of  $c_1$  as given below.

Here,

$$c_4 = \frac{1}{2}(c_1 + b)$$


The diagram shows a horizontal pink line segment from 'a' to 'b'. There are two pink dots: 'c1' at the midpoint and 'c4' to its right.

$$c_5 = \frac{1}{2}(c_4 + b)$$


The diagram shows a horizontal pink line segment from 'a' to 'b'. There are three pink dots: 'c1' at the midpoint, 'c4' to its right, and 'c5' to the right of 'c4'.

This clearly shows that average of two numbers, in general, always lie between them.

For example, the average of  $\frac{1}{4}$  and  $\frac{3}{8} = \frac{1}{2}\left(\frac{1}{4} + \frac{3}{8}\right)$

$$= \frac{1}{2}\left(\frac{5}{8}\right) = \frac{5}{16}$$

Here,  $\frac{1}{4} = \frac{1}{4} \times \frac{4}{4} = \frac{4}{16}$  and  $\frac{3}{8} = \frac{3}{8} \times \frac{2}{2} = \frac{6}{16}$

Thus, we find that the average  $\frac{5}{16}$  lies between  $\frac{4}{16}$  and  $\frac{6}{16}$ .

That is,  $\frac{1}{4} < \frac{5}{16} < \frac{3}{8}$

Hence, the average of two numbers lies between the two numbers.

**Example 1.5**

Find 6 rational numbers between  $\frac{-7}{11}$  and  $\frac{5}{-9}$ .

**Solution:**

**Method 1:**

LCM of 11 and 9 =  $11 \times 9 = 99$

$$\frac{-7}{11} = \frac{-7 \times 9}{11 \times 9} = \frac{-63}{99}$$

$$\frac{5}{-9} = \frac{5 \times (-1)}{-9 \times (-1)} = \frac{-5}{9} \times \frac{11}{11} = \frac{-55}{99}$$

Therefore, 6 rational numbers between  $\frac{-7}{11}$  ( $= \frac{-63}{99}$ ) and  $\frac{5}{-9}$  ( $= \frac{-55}{99}$ ) are

$$\frac{-63}{99}, \frac{-56}{99}, \frac{-57}{99}, \frac{-59}{99}, \frac{60}{99}, \frac{-61}{99}, \frac{-62}{99}, \frac{-55}{99}.$$

**Think:** Are there any rational numbers between  $\frac{-7}{11}$  and  $\frac{6}{-11}$ ?

**Method 2:**

The average of  $a$  and  $b$  is  $\frac{1}{2}(a + b)$

The average of  $\frac{-7}{11}$  and  $\frac{5}{-9}$  is  $c_1 = \frac{1}{2}\left(\frac{-7}{11} + \frac{-5}{9}\right)$

$$= \frac{1}{2}\left(\frac{-63 - 55}{99}\right) = \frac{1}{2}\left(\frac{-118}{99}\right)$$

$$c_1 = \frac{-59}{99}$$

$$\therefore \frac{-7}{11} < \frac{-59}{99} < \frac{5}{-9} \dots (1)$$

The average of  $\frac{-7}{11}$  and  $\frac{-59}{99}$  is  $c_2 = \frac{1}{2}\left(\frac{-7}{11} + \frac{-59}{99}\right)$

$$= \frac{1}{2}\left(\frac{-63 - 59}{99}\right)$$

$$c_2 = \frac{1}{2} \times \frac{-122}{99} = \frac{-61}{99}$$

$$\therefore \frac{-7}{11} < \frac{-61}{99} < \frac{-59}{99} \dots (2)$$

The average of  $\frac{-59}{99}$  and  $\frac{-5}{9}$  is  $c_3 = \frac{1}{2}\left(\frac{-59}{99} + \frac{-5}{9}\right)$

$$= \frac{1}{2} \left( \frac{-55 - 59}{99} \right)$$

$$c_3 = \frac{1}{2} \left( \frac{-114}{99} \right) = \frac{-57}{99}$$

$$\therefore \frac{-59}{99} < \frac{-57}{99} < \frac{5}{-9} \dots (3)$$

Combining (1), (2) and (3), we get  $\frac{-7}{11} < \frac{-61}{99} < \frac{-59}{99} < \frac{-57}{99} < \frac{5}{-9}$ . Thus, we have found 3 rational numbers between  $\frac{-7}{11}$  and  $\frac{5}{-9}$ . Similarly, try to find 3 more rational numbers in between  $\frac{-7}{11}$  and  $\frac{5}{-9}$  in the same way.

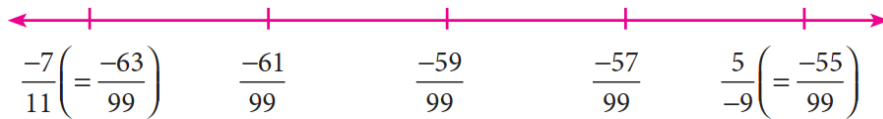


Fig. 1.9

That is,  $\frac{-7}{11} < \frac{-61}{99} < \frac{-59}{99} < \frac{-57}{99} < \frac{5}{-9}$

**Note**

We can find many rational numbers between  $\frac{-7}{11}$  and  $\frac{5}{-9}$  quickly as given below: The range of rational numbers can be got by the cross multiplication of denominators with the numerators after writing the given fractions in standard form. The cross multiplication here

$\frac{-7}{11} \times \frac{-5}{9}$  gives the range of rational numbers from -63 to -55 with denominator 99.

**1.3 - Four Basic Operations On Rational Numbers**

**1.3.1 - Addition**

**(i) Addition of rational numbers with the same denominators**

Add only the numerators of the two or more rational numbers and write the same denominator.

**Example 1.6**

Add:  $\frac{-6}{11}, \frac{8}{11}, \frac{-12}{11}$

**Solution:**

Write the given rational numbers in the standard form and add them.

$$\frac{-6}{11} + \frac{8}{11} + \frac{-12}{11} = \frac{-6 + 8 - 12}{11} = \frac{-10}{11}$$

**(ii) Addition of rational numbers with different denominators:**

After writing the given rational numbers in the standard form, take the LCM of the denominators of the given rational numbers and convert them to equivalent rational numbers with common denominators (LCM) and then, add the numerators.

**Example 1.7**

Add:  $\frac{-5}{9}, \frac{-4}{3}, \frac{7}{12}$

**Solution:**

LCM of 9,3,12 = 36

$$\begin{aligned}\frac{-5}{9} + \frac{-4}{3} + \frac{7}{12} &= \frac{-5}{9} \times \frac{4}{4} + \frac{-4}{3} \times \frac{12}{12} + \frac{7}{12} \times \frac{3}{3} \\ &= \frac{-20}{36} + \frac{-48}{36} + \frac{21}{36} = \frac{-20 - 48 + 21}{36} \\ &= \frac{-47}{36}\end{aligned}$$

### 1.3.2 - Additive Inverse

What is  $\frac{-8}{11} + \frac{8}{11}$ ?

$$\text{Now, } \frac{-8}{11} + \frac{8}{11} = \frac{-8+8}{11} = \frac{0}{11} = 0$$

$$\text{Also, } \frac{8}{11} + \left(\frac{-8}{11}\right) = \frac{8-8}{11} = \frac{0}{11} = 0$$

In the case of integers, we say  $-5$  as the additive inverse of  $5$  and  $5$  as the additive inverse of  $-5$ . Here, for rational numbers,  $\frac{-8}{11}$  is the additive inverse of  $\frac{8}{11}$  and  $\frac{8}{11}$  is the additive inverse of  $\frac{-8}{11}$ .

### 1.3.3 - Subtraction

Subtracting two rational numbers, is the same as adding the additive inverse of the second rational number to the first rational number.

**(i) Subtraction of rational numbers with the same denominators**

Subtract only the numerators of the two or more rational numbers and write the same denominator.

**(ii) Subtraction of rational numbers with different denominators:**

After writing the given rational numbers in the standard form, take the LCM of the denominators of the two given rational numbers and convert them to equivalent rational numbers with common denominators (LCM) and then, subtract the numerators.

#### Example 1.8

Subtract  $\frac{9}{17}$  from  $\frac{-12}{17}$

**Solution:**

$$\text{Now, } \frac{-12}{17} - \frac{9}{17} = \frac{-12-9}{17} = \frac{-21}{17}$$

#### Example 1.9

Subtract  $\frac{-180}{225}$  from  $\frac{200}{225}$

**Solution:**

$$\text{Now, } \frac{200}{225} - \left(\frac{-180}{225}\right) = \frac{200+180}{225} = \frac{300}{225} = \frac{4}{3}$$

**Example 1.10**

Subtract  $\left(-2\frac{6}{11}\right)$  from  $\left(-4\frac{5}{22}\right)$

**Solution:**

$$\begin{aligned}\text{Now, } & \left(-4\frac{5}{22}\right) - \left(-2\frac{6}{11}\right) \\ &= \frac{-93}{22} - \left(\frac{-28}{11}\right) \\ &= \frac{-93}{22} + \frac{28}{11} \\ &= \frac{-93 + 28 \times 2}{22} \\ &= \frac{-93 + 56}{22} = \frac{-37}{22} = -1\frac{15}{22}\end{aligned}$$

### 1.3.4 - Multiplication

Product of two or more rational numbers can be found by multiplying the corresponding numerators and denominators of the numbers and then write them in the standard form.

**Example 1.11**

evaluate

- (i)  $\frac{-5}{8} \times 7$
- (ii)  $\frac{-6}{-11} \times (-4)$

**Solution:**

- (i)  $\frac{-5}{8} \times 7 = \frac{-5}{8} \times \frac{7}{1} = \frac{-5 \times 7}{8 \times 1} = \frac{-35}{8}$
- (ii)  $\frac{-6}{-11} \times (-4) = \frac{6}{11} \times \frac{(-4)}{1} = \frac{6 \times (-4)}{11 \times 1} = \frac{-24}{11}$

### 1.3.5 - Product Of Reciprocals And The Multiplicative Inverse

If the product of two rational numbers is 1, then one rational number is said to be the reciprocal or the multiplicative inverse of the other.

For the rational number  $a$ , its reciprocal is  $\frac{1}{a}$  as  $a \times \frac{1}{a} = \frac{a}{a} \times 1 = 1$ .

For the rational number  $\frac{a}{b}$ , its multiplicative inverse is  $\frac{b}{a}$  as  $\frac{a}{b} \times \frac{b}{a} = \frac{b}{a} \times \frac{a}{b} = 1$ .

### 1.3.6 - Division

We have seen about the reciprocals of fractions in the earlier classes. The same idea of reciprocals is extended to rational numbers also.

To divide a rational number by another rational number, we have to multiply the rational number by the reciprocal of another rational number.

#### Example 1.12

Divide  $\frac{7}{-8}$  by  $\frac{-3}{4}$

**Solution:**

$$\frac{7}{-8} \div \frac{-3}{4} = \frac{-7}{8} \times \frac{-4}{3} = \frac{7}{6}$$

### 1.4 - Word Problems On These Operations

#### Example 1.13

The sum of two rational numbers is  $\frac{4}{5}$ . If one number is  $\frac{2}{15}$ , find the other.

**Solution:**

Let the other number be  $x$

$$\text{Given, } \frac{2}{15} + x = \frac{4}{5}$$

$$\Rightarrow x = \frac{4}{5} - \frac{2}{15} = \frac{12 - 2}{15} = \frac{10}{15}$$

$$\Rightarrow x = \frac{2}{3}$$

**Try this**

Divide

(i) 5 by  $\frac{-7}{3}$

(ii)  $\frac{-7}{3}$  by 5

#### Example 1.14

The product of two rational numbers is  $\frac{-2}{3}$ . If one number is  $\frac{3}{7}$ , find the other.

**Solution:**

Let the other number be  $x$

$$\text{Given, } \frac{3}{7}x = \frac{-2}{3}$$

Multiplying by the reciprocal of  $\frac{3}{7}$ , that is  $\frac{7}{3}$ ,

$$\Rightarrow \frac{7}{3} \times \frac{3}{7} \times x = \frac{7}{3} \times \frac{-2}{3}$$

$$\Rightarrow x = \frac{-14}{9}$$

**Aliter**

$$\frac{3}{7}x = \frac{-2}{3}$$

$$\Rightarrow x = \frac{-2}{3} \times \frac{7}{3} = \frac{-14}{9}$$

**Example 1.15**

One roll of ribbon is  $18\frac{3}{4}m$  long. Sankari has four full rolls and one – third of a roll. How many metres of ribbon does Sankari have in total?



Fig. 1.10

**Solution:**

Number of metres of ribbon Sankari has

$$= 18\frac{3}{4} \times 4\frac{1}{3}$$

$$\frac{75}{4} \times \frac{13}{3} = \frac{325}{4} = 81\frac{1}{4}m$$

**Special Examples:**

**Example 1.16**

Find the rational numbers that should be added and subtracted that will make the sum  $3\frac{1}{2} + 1\frac{3}{4} + 2\frac{3}{8}$  to the nearest whole number.

**Solution:**

$$\text{Now, } 3\frac{1}{2} + 1\frac{3}{4} + 2\frac{3}{8}$$

$$\begin{aligned}
&= \frac{7}{2} + \frac{7}{4} + \frac{19}{8} \\
&= \frac{7 \times 4 + 7 \times 2 + 19 \times 1}{8} = \frac{28 + 14 + 19}{8} \\
&= \frac{61}{8} = 7\frac{5}{8}, \text{ which lies between the whole numbers 7 and 8.}
\end{aligned}$$

$$\text{Now, } \frac{64}{8} = 8 \text{ and } \frac{56}{8} = 7$$

Therefore, the rational number to be added to  $\frac{61}{8}$  to get  $\frac{64}{8}$  is  $\frac{64}{8} - \frac{61}{8} = \frac{3}{8}$  and the rational number to be subtracted from  $\frac{61}{8}$  to get  $\frac{56}{8}$  is  $\frac{61}{8} - \frac{56}{8} = \frac{5}{8}$ .

### Example 1.17

A student instead of multiplying a number by  $\frac{8}{9}$ , divided it by  $\frac{8}{9}$  by mistake. If the difference between the answers got by him is 34, find the number.

#### Solution:

Let  $x$  be the number.

The student had to find  $\frac{8x}{9}$  but,

he had found  $\frac{x}{(\frac{8}{9})}$ , that is  $\frac{9x}{8}$

$$\text{Now, } \frac{9x}{8} - \frac{8x}{9} = 34$$

$$\frac{81x - 64x}{72} = 34 \Rightarrow \frac{17x}{72} = 34$$

$$x = \frac{34 \times 72}{17} = 144$$

#### Note:

For any non-zero  $b$ ,  $c$ , and  $d$ , we have

$$(i) \left(\frac{a}{b}\right) \div c = \frac{a}{bc}$$

$$(ii) a \div \left(\frac{b}{c}\right) = \frac{ac}{b}$$

$$(iii) \left(\frac{a}{b}\right) \div \left(\frac{c}{d}\right) = \frac{ad}{bc}$$

### Example 1.18

$$\text{Evaluate: } \left(\frac{4}{3} - \left(\frac{-3}{2}\right)\right) + \left(\frac{-5}{3} \div \frac{30}{12}\right) + \left(\frac{-12}{9} \times \frac{-27}{16}\right)$$

**Solution:**

$$\begin{aligned}\left(\frac{4}{3} - \left(\frac{-3}{2}\right)\right) + \left(\frac{-5}{3} \div \frac{30}{12}\right) + \left(\frac{-12}{9} \times \frac{-27}{16}\right) &= \left(\frac{4}{3} + \frac{3}{2}\right) + \left(\frac{-5}{3} \times \frac{12}{30}\right) + \left(\frac{-12}{9} \times \frac{-27}{16}\right) \\ &= \left(\frac{8}{6} + \frac{9}{6}\right) + \left(\frac{-1}{1} \times \frac{4}{6}\right) + \left(\frac{-3}{1} \times \frac{-3}{4}\right) \\ &= \left(\frac{17}{6}\right) + \left(\frac{-4}{6}\right) + \left(\frac{9}{4}\right) \\ &= \left(\frac{17-4}{6}\right) + \frac{9}{4} = \frac{13}{6} + \frac{9}{4} \\ &= \frac{26+27}{12} = \frac{53}{12}\end{aligned}$$

**Example 1.19**

In the NEET exam, out of a total of 180 questions, Jeyanth answered  $\frac{19}{30}$  of the questions correctly and  $\frac{5}{18}$  of the questions incorrectly. How many questions did Jeyanth not attend at all?

**Solution:**

Questions answered correctly by Jeyanth =  $\frac{19}{30} \times 180 = 19 \times 6 = 114$

Questions answered incorrectly by Jeyanth =  $\frac{5}{18} \times 180 = 50$

$$\begin{aligned}\therefore \text{Number of questions not attended by Jeyanth} &= 180 - (114 + 50) \\ &= 180 - 164 = 16\end{aligned}$$

**Exercise - 1.1**

1. Fill in the blanks:

- (i)  $\frac{-19}{5}$  lies between the integers \_\_\_ and \_\_\_.
- (ii) The rational number that is represented by 0.44 is \_\_\_.
- (iii) The standard form of  $\frac{+58}{-78}$  is \_\_\_.
- (iv) The value of  $\frac{-5}{12} + \frac{7}{15}$  = \_\_\_.
- (v) The value of  $\left(\frac{-15}{23}\right) \div \left(\frac{+30}{-46}\right)$  is \_\_\_.

2. Say True or False:

- (i) 0 is the smallest rational number.
- (ii) There are an unlimited number of rational numbers between 0 and 1.
- (iii) The rational number which does not have a reciprocal is 0.

### 1.5.1 - Closure Property

The collection of rational numbers ( $Q$ ) is closed under addition and multiplication. This means for any two rational numbers  $a$  and  $b$ ,  $a + b$  and  $a \times b$  are unique rational numbers.

#### Illustration

$$\text{Take } a = \frac{3}{4} \text{ and } b = \frac{-1}{2}$$

$$\text{Now, } a + b = \frac{3}{4} + \frac{-1}{2} = \frac{3}{4} + \frac{-2}{4} = \frac{3-2}{4} = \frac{1}{4} \text{ is in } Q$$

$$\text{Also, } a \times b = \frac{3}{4} \times \frac{-1}{2} = \frac{-3}{8} \text{ is in } Q$$

#### Try this

The closure property on integers holds for subtraction and not for division. What about rational numbers? Verify.

### 1.5.2 - Commutative Property

Addition and multiplication are commutative for rational numbers. That is, for any two rational numbers  $a$  and  $b$ ,

(i)  $a + b = b + a$  and

(ii)  $a \times b = b \times a$



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#### Illustration

$$\text{Take } a = \frac{-7}{8} \text{ and } b = \frac{3}{5}$$

$$\text{Now, } a + b = \frac{-7}{8} + \frac{3}{5} = \frac{-7 \times 5 + 3 \times 8}{40} = \frac{-35 + 24}{40} = \frac{-11}{40}$$

$$\text{Also, } b + a = \frac{3}{5} + \frac{-7}{8} = \frac{3 \times 8 + -7 \times 5}{40} = \frac{24 - 35}{40} = \frac{-11}{40}$$

We find  $a + b = b + a$  and hence addition is commutative.

Further,

$$a \times b = \frac{-7}{8} \times \frac{3}{5} = \frac{-7 \times 3}{8 \times 5} = \frac{-21}{40}$$

$$\text{Also, } b \times a = \frac{3}{5} \times \frac{-7}{8} = \frac{3 \times -7}{5 \times 8} = \frac{-21}{40}$$

Thus,  $a \times b = b \times a$  and hence multiplication is commutative.

### Try these

(i) Check whether  $\frac{3}{5} - \frac{7}{8} = \frac{7}{8} - \frac{3}{5}$

(ii) Is  $\frac{3}{5} \div \frac{7}{8} = \frac{7}{8} \div \frac{5}{3}$ ? So, what do you conclude?

### 1.5.3 - Associative Property

Addition and multiplication are associative for rational numbers.

That is, for any three rational numbers  $a$ ,  $b$  and  $c$ ,

(i)  $(a + b) + c = a + (b + c)$  and

(ii)  $(a \times b) \times c = a \times (b \times c)$

#### Illustration

Take rational numbers  $a, b, c$  as  $a = \frac{-1}{2}$ ,  $b = \frac{3}{5}$ ,  $c = \frac{-7}{10}$

Now,  $a + b = \frac{-1}{2} + \frac{3}{5} = \frac{-5}{10} + \frac{6}{10}$  (equivalent rationals with common denominators)

$$a + b = \frac{-5 + 6}{10} = \frac{1}{10}$$

$$(a + b) + c = \frac{1}{10} + \left(\frac{-7}{10}\right) = \frac{1-7}{10} = \frac{-6}{10} = \frac{-3}{5} \dots (1)$$

Also,

$$b + c = \frac{3}{5} + \frac{-7}{10} = \frac{6}{10} + \frac{-7}{10} = \frac{6-7}{10} = \frac{-1}{10}$$

$$a + (b + c) = \frac{-1}{2} + \frac{-1}{10} = \frac{-5}{10} + \frac{-1}{10} = \frac{-5-1}{10} = \frac{-6}{10} = \frac{-3}{5} \dots (2)$$

**(1)** and **(2)** shows that  $(a + b) + c = a + (b + c)$  is true for rational numbers.

Now,

$$a \times b = \frac{-1}{2} \times \frac{3}{5} = \frac{-1 \times 3}{2 \times 5} = \frac{-3}{10}$$

$$(a \times b) \times c = \frac{-3}{10} \times \frac{-7}{10} = \frac{-3 \times -7}{10 \times 10} = \frac{-21}{100} \dots (3)$$

Also,

$$b \times c = \frac{3}{5} \times \frac{-7}{10} = \frac{3 \times -7}{5 \times 10} = \frac{-21}{50}$$

$$a \times (b \times c) = \frac{-1}{2} \times \frac{-21}{50} = \frac{-1 \times -21}{2 \times 50} = \frac{21}{100} \dots (4)$$

**(3)** and **(4)** shows that

$(a \times b) \times c = a \times (b \times c)$  is true for rational numbers. Thus, the associative property is true for addition and multiplication of rational numbers.

**Think:**

Observe that,  $\frac{1}{1.2} + \frac{1}{2.3} = \frac{2}{3}$

$$\frac{1}{1.2} + \frac{1}{2.3} + \frac{1}{3.4} = \frac{3}{4}$$

$$\frac{1}{1.2} + \frac{1}{2.3} + \frac{1}{3.4} + \frac{1}{4.5} = \frac{4}{5}$$

Use your reasoning skills, to find the sum of the first 7 numbers in the pattern given above.

**Try this**

Check whether associative property holds for subtraction and division.

### **1.5.4 - Additive And Multiplicative Identity Property**

The identity for addition is **0** and the identity for multiplication is **1**.

For any rational number  $a$  there exists unique identity elements **0** and **1** such that

- (i)  $\mathbf{0} + a = a$  and
- (ii)  $\mathbf{1} \times a = a$

**Illustration**

Take  $a = \frac{3}{-7}$  that is,  $a = \frac{-3}{7}$  Now  $\frac{-3}{7} + 0 = \frac{-3}{7} = 0 + \frac{-3}{7}$  (Why?)

Hence, 0 is the additive identity for  $\frac{-3}{7}$

Also,  $\frac{-3}{7} \times 1 = \frac{-3}{7} = 1 \times \frac{-3}{7}$  (Why?)

Hence, 1 is the multiplicative identity for  $\frac{-3}{7}$ .

### **1.5.5 - Additive And Multiplicative Inverse Property**

For any rational number  $a$  there exists a unique rational number  $-a$  such that  $a + (-a) = 0 = (-a) + a$  (Additive Inverse property).

For any non-zero rational number  $b$  there exists a unique rational number  $\frac{1}{b}$  such that  $b \times \frac{1}{b} = 1 = \frac{1}{b} \times b$  (Multiplicative Inverse property).

**Illustration**

Take  $a = \frac{-11}{23}$  Now,  $-a = -\left(\frac{-11}{23}\right) = \frac{11}{23}$

$$\text{Now, } a + (-a) = \frac{-11}{23} + \frac{11}{23} = \frac{-11+11}{23} = \frac{0}{23} = 0$$

$$\text{Also, } (-a) + a = \frac{11}{23} + \frac{-11}{23} = \frac{11-11}{23} = \frac{0}{23} = 0$$

$\therefore a + (-a) = (-a) + a = 0$  is true.

$$\text{Also, take } b = \frac{-17}{29} \text{ Now, } \frac{1}{b} = \frac{29}{-17} = \frac{-29}{17}$$

$$b \times \frac{1}{b} = \frac{-17}{29} \times \frac{-29}{17} = 1$$

$$\text{Also, } \frac{1}{b} \times b = \frac{-29}{17} \times \frac{-17}{29} = 1$$

$$\therefore b \times \frac{1}{b} = \frac{1}{b} \times b = 1 \text{ is true.}$$

### Do You Know?

We know that different operations with the same rational numbers usually give different answers. But the following calculations are some interesting exceptions in rational numbers.

$$(i) \quad \frac{13}{4} + \frac{13}{9} = \frac{13}{4} \times \frac{13}{9}$$

$$(ii) \quad \frac{169}{30} + \frac{13}{15} = \frac{169}{30} \div \frac{13}{15}$$

Amazing ...! Isn't it? Try a few more like these, if possible.

### 1.5.6 - Distributive property

Multiplication is distributive over addition for the collection of rational numbers.

For any three rational numbers  $a$ ,  $b$  and  $c$ ,

$$a \times (b + c) = (a \times b) + (a \times c)$$

#### Illustration

Take rational numbers  $a, b, c$  as  $a = \frac{-7}{9}$ ,  $b = \frac{11}{18}$  and  $c = \frac{-14}{27}$

$$\text{Now, } b + c = b + c = \frac{11}{18} + \frac{-14}{27} = \frac{33}{54} + \frac{-28}{54} = \frac{33-28}{54} = \frac{5}{54}$$

(Equivalent rational numbers with common denominators)

$$\therefore a \times (b + c) = \frac{-7}{9} \times \frac{5}{54} = \frac{-7 \times 5}{9 \times 54} = \frac{-35}{486} \dots (1)$$

$$\text{Also, } a \times b = \frac{-7}{9} \times \frac{11}{18} = \frac{-7 \times 11}{9 \times 18} = \frac{-77}{9 \times 9 \times 2}$$

$$a \times c = \frac{-7}{9} \times \frac{-14}{27} = \frac{7 \times 14}{9 \times 9 \times 3} = \frac{98}{9 \times 9 \times 3}$$

$$\begin{aligned} \therefore (a \times b) + (a \times c) &= \frac{-77}{9 \times 9 \times 2} + \frac{98}{9 \times 9 \times 3} \\ &= \frac{-77 \times 3 + 98 \times 2}{9 \times 9 \times 2 \times 3} \\ &= \frac{-231+196}{486} = \frac{-35}{486} \dots (2) \end{aligned}$$

(1) and (2) shows that  $a \times (b + c) = (a \times b) + (a \times c)$ .

Hence, multiplication is distributive over addition for rational numbers Q.

### **Exercise - 1.2**

1. Fill in the blanks:

(i) The multiplicative inverse of  $2\frac{3}{5}$  is \_\_\_\_

(ii) If  $-3 \times \frac{6}{-11} = \frac{6}{-11} \times x$ , then x is \_\_\_\_.

(iii) If distributive property is true for  $\left(\frac{3}{5} \times \frac{-4}{9}\right) + \left(x \times \frac{15}{17}\right) = \frac{3}{5} \times (y + z)$ , then x, y, z are \_\_\_\_, \_\_\_\_ and \_\_\_\_.

(iv) If  $x \times \frac{-55}{63} = \frac{-55}{63} \times x = 1$ , then x is called the \_\_\_\_ of  $\frac{55}{63}$ .

(v) The multiplicative inverse of -1 is \_\_\_\_.