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Remote Learning of Mathematics for Visually Impaired Students during COVID-19: Exploring Online Intervention, Resources, Challenges and Issues

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Abstract. Due to COVID-19, several dramatic changes have appeared all over the world i.e., travel restrictions, healthcare shortages, self-isolation, economic crises, social distancing, increases in food demand, job losses and closure of educational institutions. This led to a rapid transition from face-to-face to remote teaching. Most remote learning platforms are designed primarily for sighted students and are less useful for visually-impaired students. Especially in mathematics, it's quite difficult for visually-impaired students to access rich visual information, such as graphs, algebraic notations, geometric shapes and statistical formulas. This article provides an overview of mathematics learning resources during the COVID-19 pandemic. It explores assistive technology-based interventions which enable visually-impaired and blind students to actively participate in remote teaching and enhance their learning skills. It was noted that solutions are available for various platforms (i.e., smartphones, tablets, laptops & desktop PCs) to support visually-impaired students. Assistive Technology in remote learning also plays a key role in enhancing the mathematical skills of visually-impaired students. Furthermore, we have investigated the important COVID-19-related resources of different institutes which are very beneficial for the online education of visually-impaired students. Moreover, some challenges and issues are discovered such as internet connectivity, lack of interaction, inadequate support, one-way communication and less effective learning. Finally, some future directions are suggested for research i.e., parents should be a part of remote learning.

Keywords: Learning, Mathematics, COVID-19, Visually Impaired, e-learning.

1   Introduction

Coronavirus was identified in 2019 in Wuhan, China. This virus was recognised globally as a pandemic in early 2020 when confirmed cases significantly increased. The World Health Organization recognized this coronavirus disease as COVID-19 on 11 February 2020 [1]. The global mortality rate peaked in January 2021 and the number of newly diagnosed cases peaked in April 2021 [2]. Due to COVID-19, educational institutions were closed and traditional teaching methods shifted to

remote learning to reduce the pandemic effects on education [3]. Teachers and students both had to learn to use remote teaching platforms. Teachers had to prepare the lecture material according to the student's expectations and in addition had their own requirements i.e., interactive virtual environments, strong collaborative environments, online support for special education, and easy content management [4]. Mathematics has its peculiar characteristics i.e., symbols, equations, formulas, language, shapes and abstraction in its concepts. Mathematics develops reasoning capabilities in the human mind and is also very important for the foundation of other science subjects [5]. Visually-impaired students face several issues when learning mathematics, such as working with graphs and diagrams [6-7]. Visually-impaired students can access information about basic math operations (i.e., addition, subtraction, multiplication and division), geometry, numbers, algebra, graphs and statistics with the help of mathematics teaching. Several instructors of visually-impaired students have reported that their students face problems in accessing mathematics graphics independently [8]. There is a need for tools, techniques, systems and web-based platforms that provide easy interaction, full encouragement and motivation to the disabled student [9].

In the CoVID-19 situation, digital learning provided better opportunities to deal with challenges [10]. Numerous computer-based applications integrated with different software and web-based packages offer virtual educational environments to empower the students learning skills [11-12]. Assistive Technology is also very useful for exploring a variety of mathematics topics. Visually-impaired students can learn many areas of mathematics with the help of assistive programs [13]. Assistive Technology provides hardware and software-based solutions which are free or commercially available for visually-impaired students and used to enhance learning and functional capabilities [14]. In mathematics, there is always a need to design and develop learning programs that could be useful for enhancing mathematical skills [15]. The National Council of Teachers of Mathematics (NCTM) in the USA has issued some principles and standards (i.e., Content standards, Process standards) for mathematics institutes. The six principles are Teaching, Learning, Curriculum, Assessment, Equity and Technology. Five important process standards are connection, reasoning, representation, communication and problem-solving skills. Five core topics in mathematics are probability, number, geometry, data analysis and algebra [16]. Researchers and developers who wish to introduce a new solution for visually impaired people can bear in mind these principles and standards to optimize the learning ability of students.

The goal of the study is to investigate the challenges and issues faced by those working in this area, the resources available, and the potential for online intervention. This study suggests ways to address the current challenges and increase the inclusivity and accessibility of online mathematics education for students who are visually impaired. This article also explores the use of remote learning tools and techniques for teaching mathematics during the COVID-19 pandemic. Also, to explores freely-available COVID-19 resources and discusses challenges and issues faced by visually-impaired students during the Covid-19 pandemic. The remaining sections are organized as follows: Section 2 reviews related work in the area of

remote learning of mathematics. Section 3 illustrates the remote learning model for visually-impaired students. Section 4 describes some COVID-19 Resources and tips for visually impaired learners. Section 5 defines the overall educational experience from different perspectives (i.e, Teaching perspective, Social perspective, Cognitive perspective and Student perspective). This section also provides an analysis of online learning during COVID-19 and discusses strengths, weaknesses, opportunities and challenges associated with this. Section 6 presents a discussion based on previous sections. Section 7 concludes the article whereas Section 8 provides the future directions for upcoming researchers and developers.

2 Related Work

This section provides a detailed review of the previous literature on remote learning of the visually impaired student. Researchers have introduced technology-based solutions to help visually-impaired students learn mathematics. Reddy et al., noted that mathematics is a very challenging subject. With the help of assistive technology, students can easily access the material and interact more effectively with the platforms to support their learning process [17]. Sokhulu et al., have provided a case study-based analysis of five masters-degree students and discussed the impact of digital technology on their learning during the COVID-19 pandemic. The findings suggested that some students were familiar with digital technologies and able to select technologies that were appropriate for them, whereas other participants did not have this awareness and faced challenges in selecting and using technology-based solutions. They also concluded that a combination of social and professional experience can address the research needs of students individually [18]. Recently, assistive technology-based solutions have proven very useful in helping visually-impaired students to acquire mathematical skills (i.e., Abacus Media, Mathematical Braille, ViewPlus Accessible Graphing Calculator, MathTalk, and MathPad Plus) [19-21].

Children with special needs required extra attention during the COVID situation. Kadarisma & Juandi proposed a qualitative approach to describe the mathematics learning process for visually-impaired children during the pandemic. They conducted interviews with teachers to obtain information on teaching materials used by them during the COVID pandemic. The results demonstrated that at the beginning of the pandemic, Alam Bandung School implemented online learning but students faced issues during video lectures. Mutiara Bunda School also used online learning through Google Meetings and assessment collection by Google Classroom. Some teachers use their learning platform (i.e., home learning guides) to provide support to the children. Overall, student learning capabilities are decreased especially in mathematics as compared to traditional teaching methods before the pandemic [22].

Rett Mcbride has discussed the finding of two articles, one of which is related to the preparation of Teachers while the second is associated with the impact of the COVID-19 pandemic on the educational experiences of students. In the first study, forty-two teachers participated, half of whom reported that they have better abilities and

experience to support mathematics students. Some reported that at the start they were not well prepared but slowly they increased their skills through self-study and professional development opportunities provided by their institutions. For the most part, they used large print or braille materials in the teaching and guidance of visually-impaired students. The second study investigated the impact of COVID-19 on different dimensions (i.e., parents concerns, access to material through technology and contacting teachers). The parents of visually impaired children are concerned about the education of their children because they lack the skills and training to educate their children at home. Parents also reported that they did not have adequate knowledge to access Braille material and mathematics educational tools. Some parents are satisfied with the teachers and instructors of their children, but others reported that the teachers don't have enough skills to understand the needs of their children [23].

3 Remote Learning-based Educational Model for Visually-impaired Students

Before the COVID-19 pandemic, visually-impaired students could easily access teaching resources, lab facilities, and classroom environments. They could also have direct communication with their teachers during the classes. Unfortunately, during the pandemic, their learning process was changed.
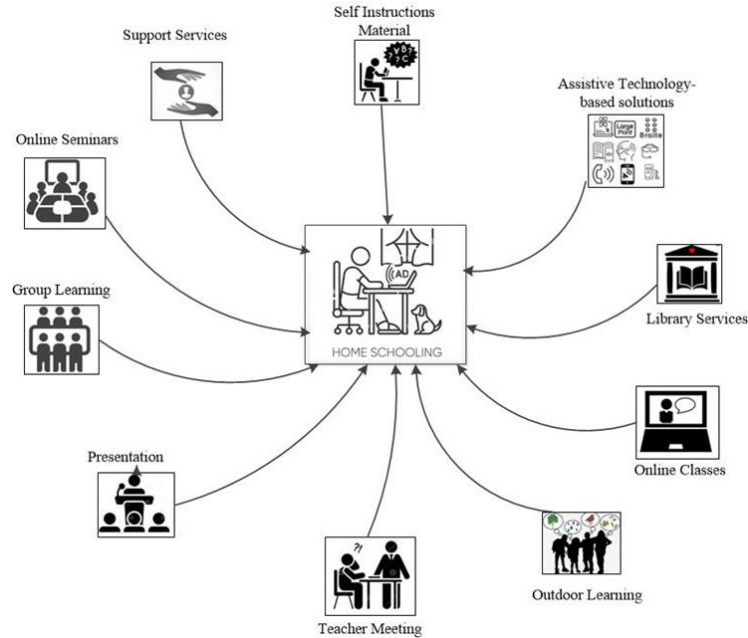

Fig. 1. Remote Learning-based educational model

Figure 1 provides an overview of the remote learning-based educational model for visually-impaired students. In this model, the focus is shifted from classroom to

homeschooling. Students can connect with educational facilities through the Internet. These educational facilities are online classes, assistive technology-based solutions, library services, outdoor learning, self-instruction material, support services, online seminars, group learning, presentations and meetings with teachers.

4   COVID-19 resources and tips for remote learning

Table 1 provides a list of useful learning resources for visually-impaired students. These resources are available on the web portals of several institutes i.e., Michigan Department of Education, The California School for the Blind, Training and Technical Assistance Centers, National Council for Special Education, Paths to Literacy for students who are blind or visually impaired and Special educational needs and disabilities. Visually-impaired students normally use these resources at their homes during the pandemic.

Table 1. Resources along with the short description

Name	Description
Michigan Department of Education[1]	These resources are collected by MDE staff members. These are very useful for families of visually-impaired students and school personnel.
The California School for the Blind[2]	These are very useful resources for remote, virtual and home learning.
Training and Technical Assistance Centers(TTAC) Online[3]	These resources have a lot of stay-at-home activities that are very useful for visually-impaired children.
National Council for Special Education(NCSE)[4]	They provide many online resources i.e., curriculum, outdoor and active learning. These resources are also very useful for visually-impaired children.
Paths to Literacy | for students who are blind or visually impaired[5]	They provide several online resources for educators and students i.e math games & activities for home.
Special educational needs and disabilities (SEND)[6]	They provide very convenient COVID-19-related resources.

[1] **https://mdelio.org/blind-visually-impaired/other-resources/covid-19-resources**
[2] **https://www.csb-cde.ca.gov/resources/covid-19/parentvirtualresources.aspx**
[3] **https://ttaconline.org/Resource/JWHaEa5BS741JNaLDkgnuA/Resource-stay-at-home-activities-for-children-with-visual-impairments-paths-to-literacy-for-students-who-are**
[4] **https://ncse.ie/all-online-resources**
[5] **https://www.pathstoliteracy.org/resources/online-learning-opportunities-schools-blind-and-related-organizations**
[6] **https://www.sthelens.gov.uk/send/support-services/visual-impairment-service/covid-19-useful-resources-for-children-with-a-visual-impairment/**

Table 2 provides a list of important remote and virtual learning-based tips that are very beneficial for visually-impaired students. These tips are listed from different electronic sources and articles that are part of our study

Table 2. Virtual Learning Tips for Visually Impaired Learners

Sr. No	Virtual Learning Tips
1	Proper Training for the online classroom.
2	Use communication options properly i.e., Zoom and Microsoft.
3	Proper use of assistive technology on top of the online classes i.e., use JAWAS
4	Online tools should be compatible with screen-reading software.
5	Use printed/magnified worksheets for braille users.
6	The whole print material should be clear and dark.
7	In colour contrast, black and white is the best option.
8	Provide a clear verbal explanation.
9	Introduce more oral activities and exercises.
10	A time limit should be more to complete the tasks.
11	Call the student's name when requires his/her attention.
12	Provide proper training to students.
13	Introduce peer tutoring to support the students.

5 Overall Educational Experience with Remote Learning

Figure 2 provides a complete overview of the educational experience through remote learning. Firstly, to obtain the desired learning outcomes from any online platform, it is important to consider the teaching perspective. Several important aspects should be kept in mind when designing a better online learning platform i.e., effective pedagogical approach, suitable use of technology, flexible learning environment and providing better assessment opportunities [24-27]. Secondly, some studies suggest that several aspects of social presence are important in remote learning i.e, teacher and student involvement, belongingness, community and participation during online sessions [28-32]. Thirdly, some articles addressed issues relating to cognitive skills, such as students need good cognitive skills to benefit from the teaching, critical reflection where learning is based upon watching, listening and engaging students by practising, doing, and thinking [33-36]. Fourthly, some studies examined the concerns of students, and these included enhanced collaboration between student and teacher, creating interpersonal relationships, and enhancing engagement during online learning [37-39].

Moreover, once the institutes switched their educational structure from face-to-face to online during COVID-19 then the parents of the students also faced issues with this transition. Some countries researched this such as the government of Luxembourg, which switched to online instruction in response to the COVID-19 pandemic. Their Ministry of Education ran a survey which revealed that more than half of the parents

had issues using remote teaching with their children. To address this issue Haas et al., used augmented reality, digital and physical-mathematical models in online learning of mathematics for primary schools. They focused on how parents can help their children access various educational instructions remotely. They suggested in online teaching parent perspective is important to enhance learning designs and associated pedagogical approaches [40].
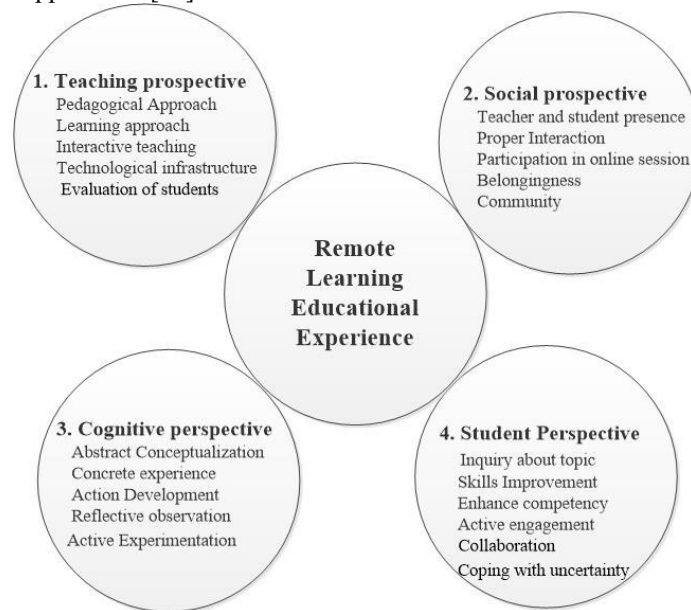

Fig. 2. Educational experience with Remote Learning

5.1 Analysis of Remote Learning During COVID

Nowadays, the educational sector faces many challenges due to the COVID-19 pandemic. Remote learning is quite useful to address these challenges. Mathematics is a very important domain of education because students have to acquire essential knowledge and skills i.e., geometry, calculus, graphs, numbers and algebra. Visually impaired students can access this information through digital and assistive technologies.

The main strength of online learning is to provide better opportunities and address the challenges faced during this time by enabling learners to customize procedures and processes. Remote learning has several weaknesses i.e., technical issues, time management and lack of personal attention. Remote learning provides many opportunities to various educational institutes in a smooth transition from traditional education methods to online educational platforms. Teachers and students can communicate better with one another through assistive technologies. Due to this paradigm shift, a lot of new opportunities are available for researchers and developers to introduce new solutions. Many challenges are also associated with online education. These challenges can be faced by students, teachers and developers. There

are different kinds of challenges i.e., lack of digital knowledge, changing the teaching methodologies, engaging students and technological costs. Figure 3 provides an analysis of remote learning during the pandemic and demonstrates the strengths, weaknesses, opportunities, and challenges associated with this situation.
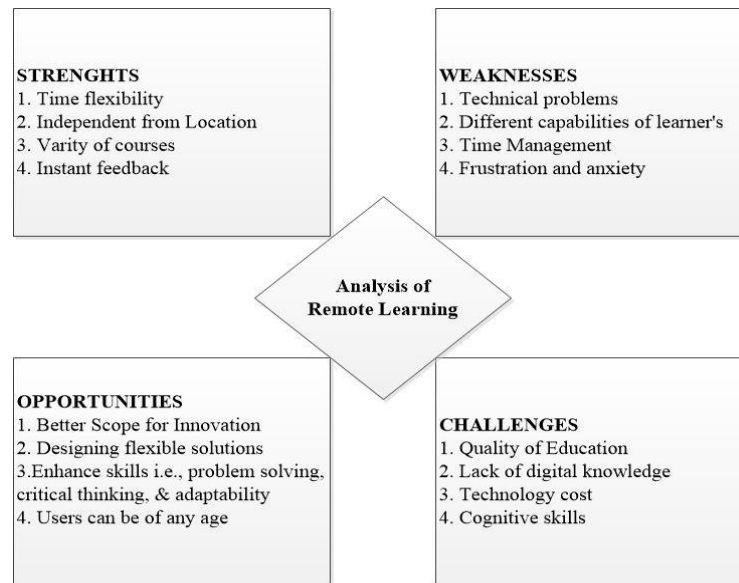

STRENGHTS
1. Time flexibility
2. Independent from Location
3. Varity of courses
4. Instant feedback

WEAKNESSES
1. Technical problems
2. Different capabilities of learner's
3. Time Management
4. Frustration and anxiety

Analysis of Remote Learning

OPPORTUNITIES
1. Better Scope for Innovation
2. Designing flexible solutions
3. Enhance skills i.e., problem solving, critical thinking, & adaptability
4. Users can be of any age

CHALLENGES
1. Quality of Education
2. Lack of digital knowledge
3. Technology cost
4. Cognitive skills

Fig. 3. Analysis of Remote Learning

6   Discussion

Many nations around the globe have adopted remote learning instead of face-to-face classes during the COVID-19 pandemic. This transition is very challenging for visually impaired students because they have special needs to access and learn mathematics. Teachers of visually impaired students played an important role during this challenging time. They have utilised a variety of resources and methods, such as screen readers, Braille materials, audiobooks and online math applications to facilitate visually impaired students through remote learning. This study has provided a remote learning-based educational model for visually impaired students. This model illustrated that the focus shifted toward homeschooling during the pandemic situation. Visually impaired students can attend online classes, access various services (i.e., library and support services) and use different assistive technology-based solutions whilst studying remotely.

We have carefully reviewed and considered the particular requirements and challenges of visually impaired students during remote learning. We have also explored the important resources and tips that were useful for visually impaired students during COVID-19. Visually impaired students have accessed the mathematical content with the help of accessible materials i.e., screen readers,

audiobooks, text-to-speech and magnification software. Visually impaired students have regularly maintained communication with their peers and teachers by using smartphones and video conferencing tools. Teachers were also able to provide them with clearer feedback on assignments to ensure that they were on track. This process helped them all to enhance their collaboration with each other. It was also noted that schools, colleges and universities also provided additional training and support to both teachers and students. This training and support helped them in understanding of remote learning platform. After that training, their abilities to use assistive technology-based solutions and accessible materials were enhanced.

In the context of earlier studies, a comprehensive model was designed to demonstrate the overall educational experience with remote learning. Four important aspects (i.e., teaching, social, cognitive and student perspective) were considered for effective online teaching and learning. Teaching perspective is very important during the designing of a remote learning platform. Better integration of technology and appropriate pedagogical approach are the key factors determining the effectiveness of the e-learning platform in teaching and learning. Social and cognitive perspectives enable teachers and students to maintain a better interpersonal relationship, trust and perceive knowledge development (according to the cognitive skills of the students). According to the student perspective, the learning process can be maximized by providing better support and interaction mechanisms to the students.

7   Conclusion

Remote learning of mathematics for visually impaired students during COVID-19 has highlighted a significant number of new issues. To cover them in this study, a remote learning-based educational model was introduced that showed the focus shifted toward homeschooling during COVID-19. This study also highlighted some important pandemic resources and tips to enhance the learning skills of visually impaired students. Moreover, a comprehensive model was developed to demonstrate the overall educational experience of visually impaired students with remote learning in mathematics.

Furthermore, a detailed analysis was conducted to examine the strengths, weaknesses, opportunities, and challenges of remote learning during the COVID-19 pandemic. Remote learning was a powerful tool in the pandemic situation. It's quite a flexible approach in the context of location and time. It's a student-centred approach and can be customized according to their needs. Remote learning platforms provide a very interactive environment by using several functionalities i.e., audio, video, touch and vibrotactile feedback. Students can easily raise queries, ask questions of their instructors and access course material from anywhere by connecting through the internet.

Some weaknesses are also associated with remote learning i.e., a communication gap between student and teacher, lack of face-to-face interaction, discipline behaviour due to time flexibility, lack of technical skills, and different cognitive and confidence levels of students. Additionally, numerous opportunities are also available for remote learning i.e., innovation in e-learning, digital solutions development, introducing

flexible solutions, effective management of the critical situation, increasing market demand and providing effective ways of teaching, learning, evaluation, assessment and so on.

Lastly, there are many challenges in remote education for students, teachers, parents, institutions, government, developers and researchers. Students require quality education, teachers want to implement their teaching methodologies, parents wish to be a part of remote learning, institutions aim to provide a better platform for learning, the government wants to implement their educational policies, developers want to tackle the concerns of stakeholders and researchers always try to find an innovative solution of the problems. These are the key areas where researchers and developers can work and design efficient educational systems for visually impaired students.

8   Future Work

Currently, lack of direct interaction with teachers is a major issue in remote learning. Researchers can introduce new innovative ways of interaction to overcome this issue. Specialized tools and applications are expensive and not readily available for visually impaired students. Developers can introduce easily accessible and cheaper solutions for visually impaired students. Furthermore, providing teachers with professional training and promoting a collaborative learning environment among visually impaired students can also facilitate remote learning in visually impaired students.

Acknowledgment

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