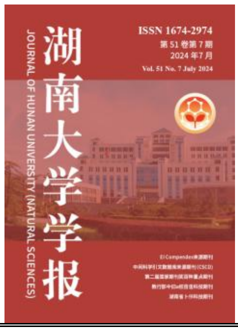

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Optimizing Online Education for Visually Impaired Students: Progress and Future Prospects

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Abstract: In the era of e-learning and educational digitization, accessibility for visually impaired students has become an urgent challenge. Despite technological advances, barriers to effectively integrating digital tools into online learning for this diverse demographic persist. This review article aims to address this critical issue by consolidating and synthesizing existing literature and suggesting solutions that promote inclusion and adaptation in the online educational environment. This literature review covers three key areas: assistive technology for visually impaired people, web and digital accessibility, and the social and educational impact of assistive technology. The importance of assistive tools such as screen readers and visual magnification software is highlighted, as well as the crucial role of web and digital accessibility in the democratization of online education. The findings reveal an urgent need to address gaps in the integration of digital tools, focusing on solutions that ensure an inclusive and adapted online learning experience. This study highlights the need for comprehensive educator training and continuous updating of assistive technologies to enhance learning experiences and promote independence among visually impaired students. Recommendations are presented for educators, course designers, and tool developers to create inclusive learning environments, develop accessible course materials, and apply universal design principles, with the goal of fostering a supportive and equitable online educational experience.

Keywords: accessibility, assistive technology, educational inclusion, e-learning, visual impairment.

优化视障学生在线教育：进展与未来前景

摘要：在电子学习和教育数字化时代，视障学生的可访问性已成为一项紧迫的挑战。尽管技术取得了进步，但将数字工具有效地整合到这一多元化群体的在线学习中仍然存在障碍。这篇评论文章旨在通过整合和综合现有文献并提出促进在线教育环境包容性和适应性的解决方案来解决这一关键问题。这篇文献综述涵盖了三个关键领域：视障人士的辅助技术、网络和数字可访问性以及辅助技术的社会和教育影响。强调了屏幕阅读器和视觉放大软件等辅助工具的重要性，以及网络和数字可访问性在在线教育民主化中的关键作用。研究结果表明，迫切需要解决数字工具整合方面的差距，重点是确保包容性和适应性的在线学习体验的解决方案。这项研究强调了对教育工作者进行全面培训和不断更新辅助技术的必要性，以增强学习体验并促进视障学生的独立性。为教育工作者、课程设计者和工具开发人员提出建议，

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以创建包容性的学习环境、开发易于理解的课程材料并应用通用的设计原则，以促进支持性和公平的在线教育体验。

关键词：无障碍、辅助技术、教育包容、电子学习、视力障碍。

1. Introduction

In the contemporary era, characterized by the digital boom and growing global interconnectedness, e-learning has emerged as a fundamental pillar of the democratization of access to education. Digital platforms have paved the way for students from all over the world to overcome geographical and temporal barriers and access high-quality educational content [1]. However, the transformative potential of e-learning faces significant obstacles, especially in terms of ensuring accessibility for learners with visual limitations [2].

The complexity and diversity of visual limitations have been widely documented, ranging from individuals with partially reduced vision to those with total blindness, with each case presenting unique challenges [3]. Nationally, statistics revealing that 27.7% of the population has some form of visual limitation underscore the urgency of adapting digital educational tools and platforms to these specific needs [4]. Although the technology industry has provided specialized tools, such as screen readers and visual magnification software [5], their integration into e-learning platforms still suffers from sub-optimalities. These shortcomings, which extend beyond the merely technological and encompass economic and cultural aspects, serve as substantial barriers [6]. Such realities invite deep reflection on how to address these challenges and ensure equitable online education.

Given the importance of online education for people with visual limitations, a key research question arises: How to ensure the integration of computer tools into e-learning that specifically meet the needs of these learners? The main objective of this review article is to consolidate and synthesize the existing literature on this topic, with the aim of contributing to academic knowledge and proposing solutions that promote inclusive and adapted online learning. The article presents a review of the literature, delves into an in-depth analysis of the results, and concludes with recommendations and suggestions for future research directions.

2. Context

Technological advancements have allowed education to transcend the traditional barriers of the classroom, giving rise to the emergence of e-learning [2], [9]. This learning modality, which uses electronic media and technologies, has democratized access to education, allowing individuals from different backgrounds to parts of the world to access quality educational content [2]. However, despite its potential, e-learning still faces significant challenges, especially in terms of accessibility [5], [38], [40].

Visual impairment, which ranges from low vision to total blindness, poses unique challenges in educational environments [5]. Individuals with visual impairment require specific adaptations and tools to fully access and benefit from educational resources [2], [7]. Although technology has advanced and offers tools such as screen readers and visual magnification software, their integration into e-learning platforms is not always optimal [5].

Ensuring accessibility in e-learning is not only an equity issue but also a legal and ethical imperative [2]. Educational institutions and developers of online learning platforms have a responsibility to ensure that all students, regardless of their abilities, have equal opportunities to learn and thrive [2].

In this context, it is essential to review and understand the current status of the integration of IT tools into e-learning for learners with visual impairment, identify existing gaps, and propose solutions for more inclusive learning [5], [8].

3. Materials and Methods

The central purpose of this review article is to synthesize part of the existing literature on online education for visually impaired people. The methodological process followed to identify, evaluate, and analyze relevant studies is detailed below.

3.1. Search Strategy

A basic search was carried out across academic databases, including JSTOR, ERIC (Education Resource Information Center), PubMed, Scopus, and other pertinent sources in the field of education and technology, such as IEEE Xplore, Association for Computing Machinery (ACM), SpringerLink, and ScienceDirect.

The following search terms and strings were included:

- Online education: "online education"; "e-learning"; "virtual education"; "online training"; "distance education"; "distance learning"
- Visual impairment: "visual disability"; "blindness"; "low vision"; "visual impairment"; "special visual needs"
- Accessibility: "accessibility"; "disability access"; "accessible design"; "accessible technologies";

"disability accommodation"

- E-learning: "e-learning"; "tele-training"; "on-line training"; "virtual teaching"; "educational technology"
- Computer tools: "computer tools"; "assistive technologies"; "educational software"; "applications for the visually impaired"; "assistive technologies"
- Undergraduate students: "undergraduate students"; "undergraduate training"; "university training"; "university level training"
- Technological integration: "technological integration"; "technologies in education"; "use of educational technologies"; "emerging technologies in education"; "implementation of technological tools"

3.2. Selection Criteria

Some characteristics were applied to include or eliminate the literature to be consulted.

3.2.1. Inclusion Criteria

- Articles and academic papers written in English or Spanish
- Published between 2000 and 2023
- Focus on the integration of computer tools into e-learning for visually impaired university students

3.2.2. Exclusion Criteria

Opinions, editorials, and studies that were not aligned with the main topic of the article were discarded.

3.3. Data Extraction

A detailed extraction matrix was created that included the main metadata for each bibliographic resource included in this research: authors, year of publication, methodology, software tools evaluated, barriers, and solutions identified.

3.4. Bibliographic Analysis

The studies were classified by computer tools, pedagogical strategies, obstacles, and solutions.

Subsequently, an in-depth qualitative analysis was conducted to identify patterns, trends, similarities, differences, and areas not explored in the literature.

Table 1 presents an analysis highlighting the best practices, effective tools and strategies, and areas for further research.

Table 1 General characteristics of the literature reviewed (The authors)

Reference	Journal/Conference	Main category
[2]	Undergraduate thesis	Social construction and web accessibility
[3]	Editorial Santillana	Education and new technologies
[4]	Not specified	Statistics and data
[10]	International Journal of Computer Science and Network Security	Evaluation of AI technologies in the education of students with visual impairment.
[16]	Education and Information Technologies	Strategies to Include Students with Visual Impairments in Online Learning
[17]	Ibero-American Journal of Education Research	E-learning curriculum design
[25, 44]	Venezuelan Journal of Informatics	Web accessibility evaluation
[34]	Independent publication	Inclusion with Visual Impairment through ICT
[35]	UNESCO Courier	Artificial Intelligence: Myth and Reality
[36]	International Trends in Electronics and Information Technology	Artificial intelligence personal assistants for visually impaired individuals
[43]	Cooperative University of Colombia	Impact of virtual education in health sciences.

4. Results

This research revealed how computational tools provide revolutionary solutions for reading and object recognition, providing visually impaired people with a new means of accessing information. In academia, the integration of artificial intelligence (AI) has driven models such as the one proposed in [10], which uses voice-activated personal assistants to improve specific tasks, such as the registration process. The combination of text mining and case-based reasoning ensures equitable access to academic resources, demonstrating the versatility and adaptability of AI in various educational contexts. The technological revolution in various sectors, particularly healthcare [43], has witnessed remarkable progress, particularly in the early detection of eye diseases through the application of advanced deep learning methods such as convolutional neural networks (CNNs). They, as outlined in recent studies [11], have facilitated the transformation of medical care and enhanced the diagnosis of diseases like diabetic retinopathy and age-related macular degeneration.

In the contemporary era, technology has revolutionized the way in which we interact with the world, offering innovative solutions that improve quality of life. However, this progress is even more significant for those who face specific challenges such as visual impairment. From the perspective of [5] and [12], assistive technology has emerged as a beacon of hope and possibility for this group, providing tools and resources that facilitate integration, learning, and autonomy. It is vital to explore in greater depth the manner in which technologies are reshaping the potential for individuals with visual impairments. This includes examining the processes of training and adapting guidance or educational strategies and assessing the present-day requirements and the specific resources at hand.

Assistive technology encompasses a diverse array of devices, applications, and resources designed to support individuals with disabilities, particularly those with visual impairments [13], [14]. These tools have a remarkable impact on the education and quality of life of people with visual impairment. For example, students with visual impairment gain significant advantages from using everything from tactile devices to specialized software, which facilitates access to the curriculum and enriches their learning experiences [11], [15], [16]. In the realm of daily living, assistive technology has manifested itself as an essential tool that promotes autonomy and active participation in society [9], [17]. Concrete examples of these technologies are applications on smartphones and specialized devices such as adapted remote controls [18], [19]. However, the effective inclusion of visually impaired people in digital environments, such as online learning, is still in its infancy [16]. A recurring obstacle is the lack of adaptation of standard technologies present in educational institutions, which often do not have the appropriate features to serve visually impaired students [16]. Despite this, it has been identified that tactile media, such as those offered by 3D printing, can be vital for teaching subjects with high visual content, such as mathematics and engineering [9]. The rapid advancement of human-machine interfaces, combined with emerging technologies, opens up new possibilities.

One innovative example is the development of a Braille writing system based on triboelectric nanogenerators, which aims to enable people with visual impairments to write without external assistance [11].

Finally, the literature highlights the need to create adapted educational platforms that promote inclusion and ensure access to education for visually impaired students. Platforms such as "Tiflo-UTM", are presented as pioneers in this direction, offering accessible and comfortable educational solutions for distance learning [13].

Accessing assistive technology is often hindered by high costs as the licenses for specific applications or software are usually beyond the reach of many individuals, particularly those with visual impairments [19]. Moreover, there is a lack of training and awareness among both users and educators about the available tools, such as browsers that integrate screen readers, which creates an additional barrier in educational settings [20], [21], [22].

The availability of this type of technology is limited in some areas and institutions, compounding the problem of access [12], [20]. In addition, incompatibility and delays in the delivery of digital and physical learning materials pose another impediment for visually impaired learners [16]. Although 3D printing has gained widespread popularity, access to 3D printable materials for educational purposes remains limited due to the expense and complexity involved in converting two-dimensional images into 3D objects [21].

The COVID-19 pandemic amplified the challenges for visually impaired individuals. During the transition to online learning, they faced problems such as the instability of Internet connections.

Internet and difficulties in accessing course materials. Teachers, for their part, had to adapt quickly to the new platforms, while parents and guardians were forced to assume the role of educators [15], [22].

The risk of exposure to the virus was higher among individuals with visual impairment who relied on touch and physical support, increasing their vulnerability. In addition, many web pages containing essential information did not satisfy the W3CAG accessibility standards, which further complicated their navigation [23].

The challenges in education are magnified in technical subjects such as mathematics and physics, where mathematical formulas present barriers to automatic conversion to speech [18]. Despite the adaptations and increasing awareness on the part of web developers, exclusion persists in educational and social contexts [8]. This lack of inclusion is also observed in university environments, such as Thailand, where websites lack adequate adaptations [8]. Despite the crucial role of assistive technologies in education, many teachers do not adequately integrate them into their teaching work [24]. This situation is evident in countries such as Tanzania, where there remains a heavy reliance on Braille materials [20].

Access to digital libraries, e-learning systems, and various other applications continues to be a challenge for people with disabilities. visual impairment [21], [22], [25], [44]. Although virtual educational platforms are available, the demand for systems designed specifically for accessibility is palpable [13]. Finally, it is crucial to recognize that individuals with visual impairments necessitate tailored adaptations that cater to their unique vision requirements, ranging from magnification to speech synthesis to Braille output [26, 45].

4.1. Importance of Training in Assistive Technologies

4.1.1. Fundamental Formation

Training in assistive technologies is an essential pillar. Users must be adequately trained to effectively use these tools and benefit fully from them [15]. Educators, especially those working with students with visual impairment, need specific training to integrate assistive technology into their pedagogical practices to enhance learning [24]. In addition, the social influence on the adoption of this technology cannot be ignored. Decisions about the implementation of assistive technology are not only technical but also influenced by professional networks and communities [24].

4.1.2. Educational Innovations and Strategies

Educational strategies have rapidly adapted to online tools to address the challenges of distance learning [15]. Apps, such as "Be My Eyes," have emerged as innovative solutions that provide immediate assistance through volunteers [23]. Innovative educational technologies such as talking pens have also been proposed to assist the visually impaired [23].

4.1.3. Current Needs and Limitations

Despite the importance of training in assistive technologies, a notable lack of information exists on the scope and content of current training programs [24].

In addition, there is an urgent need for sustainable funding in educational institutions to ensure access to and benefits from assistive technology for students with visual impairment [20].

4.1.4. Specific Tools and Platforms

The most prominent tools for visually impaired students are screen magnifiers, Braille lines, and screen reviewers. These tools ensure effective communication between the learner and the computer [18], [25], [44]. Platforms such as "Tiflo-UTM" emerge as revolutionary solutions that enable quality education for visually impaired students [13]. Other initiatives, such as distance learning platforms, are specifically designed to train people with visual impairment [22].

4.1.5. Teaching Implications and Challenges

Voice supplementation is a valuable tool that complements the reading of braille or printed texts and provides greater access to information [21]. In addition, it is essential to provide clear descriptions of the system and its contents because visually impaired users may have different perceptions of the interaction and learning processes [25, 44]. Last but not least, training teachers in the use of ICT and in the consideration of diversity is essential for ensuring inclusive and accessible education [26, 45].

According to [2], [38], [40], for people with visual impairments, browsing and using the web can present unique challenges. Recognizing this disparity, web and digital accessibility has emerged as a critical field that seeks to remove barriers and ensure equitable access for all users, regardless of their visual capabilities. Addressing the regulations, methods, and practices that promote inclusive access allows for the creation of a digital environment in which no one is excluded [25, 44].

4.1.6. Definition and Importance of Web and Digital Accessibility

Web and digital accessibility is an essential practice that seeks to design and develop online platforms and tools so that they can be used without barriers by all users, including those with visual impairment [23], [40]. As our society rapidly digitizes, this accessibility transcends from a simple add-on to an imperative need to avoid exclusion in areas such as education, employment, and social interaction [5]. This importance was accentuated during the COVID-19 pandemic. Conventional tools based on visual content disadvantaged visually impaired people, which made the urgent need for accessible distance learning tools clear [20]. In addition, the health crisis caused an abrupt transition to online education, which posed a challenge for students with special needs who lacked adequate infrastructure because their needs were driven by other aspects according to [6].

In education, digital accessibility provides equal access to content and resources. Innovative solutions such as talking pencils and text-to-speech technologies have become essential for independent learning for visually impaired students [18], [23]. However, the effectiveness of these tools depends, to a large extent, on an appropriate web design that is compatible with them [5].

Web accessibility requires that everyone, including the elderly and people with disabilities, has equal access to online information [40].

To guarantee inclusivity, it is crucial to adhere to established standards and guidelines, including the Web Content Accessibility Guidelines (WCAG) [22]. Specific tools and platforms have been developed, such as "Tiflo-UTM", with technologies that prioritize accessibility, facilitating learning for people with visual impairment [13].

In short, web and digital accessibility is focused not only on the usability of online platforms but also on ensuring that all users, regardless of their abilities, can interact, learn, and communicate effectively in an increasingly digitized world [16], [25], [44].

4.1.7. Web and Digital Accessibility Challenges

Web and digital accessibility faces many challenges ranging from lack of knowledge to rapid technological evolution [40]. One of the main obstacles is the lack of adequate training and knowledge among developers and designers. Often, they do not receive sufficient training on how to make their products accessible, which can result in the creation of content that excludes people with visual impairment [8]. In addition, understanding that visual impairment is not uniform is critical. For instance, the requirements of individuals with complete blindness are different from those of individuals with low vision [18]. As technology advances by leaps and bounds, accessibility tools and techniques must pace [38]. Otherwise, solutions can quickly become obsolete, leaving behind those who need them most [12].

In the educational context, the pandemic shed light on the existing gaps in accessible distance learning. Despite progress, significant limitations remained, particularly in the teaching of graphical information to people with visual impairment [20]. During this period, both students and teachers with visual impairment encountered unprecedented challenges, from lack of resources and support to communication problems [6], [26], [45].

Technology has its own limitations. Although there are systems that use tactile feedback to help people with visual impairments use electronic devices, they often require external power and have a limited lifespan [23]. In addition, certain content, such as mathematical formulas, is difficult to interpret using current tools [18].

Despite the existence of guidelines such as the WCAG, many sites and resources online still do not adequately implement them. The intricacy of contemporary websites, characterized by the integration of various media and multimedia elements, exacerbates the challenge of ensuring their accessibility [8]. The prevailing non-compliance with accessibility standards underscores the necessity for enhanced education and heightened awareness in this regard.

Finally, although there are tools and technologies aimed at improving accessibility, significant challenges still remain. The current solutions provided by technology do not always ensure an optimal experience for individuals with visual impairments, especially when these platforms and applications are primarily designed for sighted users [22]. In brief, despite advancements, there is still a considerable way to go to guarantee that web and digital content is entirely accessible to everyone.

4.1.8. Steps to Improve Web and Digital Accessibility

To achieve a more inclusive web and digital environment, critical steps and innovative proposals must be considered. First, a solid conceptual framework is required. An example of this is the adaptation of existing theories, such as UTAUT, to web and digital accessibility, which can guide the development and evaluation of adapted solutions [8]. However, this is not just about technical accessibility [38]. It is essential to ensure that websites and digital tools are intuitive and easy to use, especially for people with visual impairments [18]. This prioritization of usability and user experience must be accompanied by continuous training for developers and users on the latest accessibility tools and techniques. This ensures that the proposed solutions are effective and efficient [12].

Recent innovations, such as the graphical distance learning tool designed by Zhao, Mulet, Soria, Oriola, Serrano, and Jouffrais, have addressed the challenge of improving distance education for children with visual impairment. However, it is essential to maintain a balance between accessibility and usability, especially considering the challenges that visually impaired students face when learning online [20].

The proposals by Sirokman, Barlow, Rodriguez, Clark, Fogg, Eakins, and Welter regarding image design, with a view to subsequent image conversion, may be essential for optimizing the description of complex images. Moreover, the implementation of triboelectric nanogenerators (TENGs) in Braille recognition systems, which do not require an external power supply, has shown promise in fields such as human-computer interaction and virtual reality communication [23], [43].

Despite existing challenges, some students have expressed satisfaction with communication in educational settings, although mixed opinions have been expressed about the support provided by university disability services offices [6]. On the other hand, to ensure inclusive education, it is essential to provide captioning in live and recorded lectures, as well as to integrate screen readers and sign support into e-learning systems [26, 45]. It is equally crucial to avoid methods such as online slide presentations, which are incompatible with many assistive technologies [9].

In this path toward improving accessibility, proposals such as the new web-based system by Matoušek, Krňoul, Campr, Zajíc, Hanzlíček, Grůber and Kocurová, which offers user-friendly interfaces and adapted navigation, and an emphasis on accurate descriptions of images, as proposed by Sorrell, Norton, McAdams, Winterling, and Dipple, are fundamental. In addition, considering the needs of all users when designing educational tools based on the principles of universal design is essential for full inclusion [21].

Universities are also essential in this regard. For instance, Técnica de Manabí and the UNED initiatives, which include "Tiflo-UTM," demonstrate the significance of incorporating technological resources into educational models to accommodate student diversity.

In conclusion, web and digital accessibility is not only a necessity but also an opportunity to improve the inclusion of people with visual impairments. Although there are challenges, with proper training and user-centered design, web and digital tools can be ensured that are truly accessible to all.

4.1.9. Social and Educational Impact of Assistive Technologies

Assistive technology, in particular, has established itself as a fundamental bridge that transcends barriers and redefines traditional notions of ability and disability. These tools, designed specifically to assist people with disabilities, have not only transformed how they interact with the world but also reconfigured the educational and social spaces in which they function, as explained by [24]. From the position of [7], as we dive into the social and educational impact of assistive technology, we explore how these innovations have created opportunities, fostered independence, and cemented a path toward a more inclusive and equitable society.

4.1.10. Social Value of Technology Assistance

Assistive technology has established itself as an indispensable tool for people with visual impairment because it enhances their inclusion in society and enables them to interact and contribute in a meaningful way. These technologies are instrumental in breaking down barriers, reducing isolation, and promoting greater social integration [6], [21]. One of the most tangible advantages is empowerment toward independence. These tools enable people with visual impairment to perform daily and professional tasks autonomously, thus reinforcing their autonomy and self-esteem [15], [20]. In the workplace, assistive technology has broadened the horizon of opportunities, mitigating the unemployment and dependency rates of this demographic group [15], [20]. In the educational context, technology has proven to be a vehicle for empowerment. Tools such as Zoom and FaceTime, whose free versions were not sufficient and required the purchase of licenses per user and adaptations in museums and exhibitions, have been essential to facilitate access and enrich the experiences of people with visual impairment [16], [23], [25], [44]. Web accessibility is essential for ensuring social equality and enabling access to information for all, including individuals with disabilities [9]. In addition, an increase in writing accuracy and fluency has been observed among students with visual impairment due to assistive technologies [20].

Identification with communities of practice (CoP) has been vital for teachers of students with visual impairment to keep abreast of technological advances [24], [42]. Information and communication technologies (ICT) and assistive tools can redefine education and society and foster inclusion and autonomy [8]. Examples such as the "Tiflo-UTM" platform and the collaboration of UNED with organizations such as the ONCE Foundation and CERMI underscore the positive social impact and importance of inclusive social awareness [13], [25], [26], [44], [45]. In conclusion, assistive technologies not only make life easier for people with visual impairment but also play a crucial role in their integration into and success in society and the educational environment.

4.2. Educational Implications of Assistive Technologies

Assistive technologies seek to provide equitable access to education and ensure that students with visual impairment have the opportunity to access the same resources as their peers, as noted by [21] and [24]. In addition, these tools are designed to facilitate learning by adapting to the individual needs of each learner, which improves their comprehension and retention, according to [18] and [20]. However, assistive technology goes beyond facilitating access to content; it also reinforces essential skills such as communication, self-management, and problem-solving, as indicated by [24], [25], [44].

The COVID-19 pandemic has driven a rapid transition to digital education, which presents challenges and opportunities for the education of visually impaired students. While some have faced barriers to online learning, the situation has highlighted the need for more accessible learning environments, as discussed by [26], [27], [28], [45]. However, the mere adoption of technologies in education does not guarantee accessibility for all [39]. It is essential that the implementation of technology takes into account all learners to ensure that platforms and resources are accessible, as suggested by [24] and [32].

Teacher training is essential for the success of assistive technologies. The ability and competence of educators to adapt curricula and methodologies are vital for taking full advantage of these tools, as highlighted by [15] and [24]. In terms of innovations and developments, there are emerging proposals, such as more intuitive Braille writing systems and online educational platforms with visual and auditory modes, which seek to improve the educational experience of students with visual impairment, according to [10] and [18].

Educational institutions and various organizations are taking active steps to promote inclusion and accessibility. From the creation of inclusive educational platforms to collaborations between universities and foundations, these actions represent significant progress toward a more inclusive education, as indicated by [13], [26], [45]. In addition, ICT with assistive technologies (AT) can broaden educational horizons. These technologies offer access to online courses, forums, and other digital learning modes, promoting a more inclusive education, as noted by [22] and [29]. In summary, ATs have broad educational implications, highlighting their potential to improve access and quality of education for students with visual impairment and emphasizing the importance of training and adaptability in their implementation [30].

4.3. Challenges and Future Considerations

Training educators in the use of assistive technologies is essential for effectively integrating these tools into the classroom, as noted by [24]. During the COVID-19 pandemic, this need became even more evident as the importance of training educators in the use of online learning and distance education was underscored. Communication and support for educators during unexpected events, such as the pandemic, are crucial to ensure learning continuity. In addition, it is vital to consider all disabilities when designing e-learning systems and to adopt a more learner-centered e-learning methodology [3], [25], [44]. Regarding technology and assistive tools, they require constant updates because of rapid technological evolution, as mentioned by [31]. Innovative tools are being developed, such as graphical distance learning solutions and image accessibility in STEM texts using 3D printing. However, challenges remain in their development and implementation [32], [43]. Despite advances, the full availability of educational materials such as mathematics textbooks remains a challenge. Although web accessibility has established guidelines, it still faces significant obstacles [21]. It is essential to pay attention to diversity when selecting and using assistive technologies because there are different types of visual impairment and individual needs [18]. The COVID-19 pandemic specifically affected visually impaired students who faced challenges related to physical health, access to medical treatment, and psychological issues. Inclusive design of online content and exhibits is crucial for ensuring accessibility. In addition, systems and devices must allow these students to directly verify information [28]. At the policy and guideline levels, current policies and guidelines need to be more relevant to the inclusion of students with visual impairments in online learning [28]. The pandemic highlighted the need for stronger policies that protect the rights of these learners and ensure better access to services, technology, and information in crises. Although guidelines for web accessibility exist, their implementation faces significant challenges [24]. Finally, to ensure effective adoption of assistive technologies, developers must consider not only how learners with visual impairments will use these tools but also how they can support their implementation by educators [32]. Despite the obvious benefits of assistive technologies, their implementation faces challenges such as a lack of knowledge about their use and a shortage of devices [25], [44]. Although progress has been made in inclusion, there are still pending areas of research in the field of inclusive and effective education [15]. "Tiflo-UTM" represents a step toward more inclusive education in Ecuador, but there are still areas that require improvement [21]. The virtual learning platform "Tiflo-UTM" is a pioneering tool in Ecuador for quality education for students with visual impairment [41]. It provides easier and more comfortable and accessible information technology [13]. Teachers who have students in these conditions can add content from established curricula and allow everyone to follow a linear learning process that is free from the time and space constraints typical of face-to-face teaching [13]. Ecuadorian regulations currently advocate for universal education in accordance with the guidelines outlined in the Toda una Vida National Plan [13]. Although progress has been made, a deficit remains in the provision of tools for people with visual impairment. Therefore, there is a need to implement Tiflo-UTM [13].

4.4. AI

The technological revolution in the field of AI is generating profound changes in the lives of people with visual impairment. These transformations are driven by a number of innovations that address both the medical and everyday challenges faced by this population group. One of the most notable advances in the medical field is the ability of AI to diagnose eye diseases [33]. Deep learning techniques, especially CNNs, are essential tools for retinal image processing. These networks facilitate early detection of diseases such as diabetic retinopathy (DR) and age-related macular degeneration (AMD). In addition, technologies such as generative adversarial networks (GANs) and transfer learning further refine this process, optimizing diagnostic accuracy and reducing the need for large datasets [11].

In the realm of everyday life, AI-based solutions offer assistance in crucial areas such as reading and object recognition. Assistive reading systems, for example, revolutionize the way visually impaired people access information [34], [35]. These systems, which employ advanced image and text recognition algorithms, convert visual information to audio, facilitating access to texts and signs. The YOLO algorithm, in particular, has proven effective in detecting objects in real time and provides auditory information that helps people interpret their environments [36].

Mobility is another area that is benefiting greatly from AI. Traditional solutions, such as white canes, are useful, but they have limitations. In contrast, [19] and [35] expose that recent AI innovations offer obstacle avoidance systems that use visual recognition and advanced sensors. These solutions can detect and communicate information about obstacles at a distance or in the air, providing visually impaired people with unprecedented autonomy.

Finally, the academic world is not lagging behind in the adoption of AI to improve the educational experiences of visually impaired students. Models, such as the one proposed in [10], employ voice-activated personal assistants for specific tasks such as enrollment. The combination of text mining and case-based reasoning (CBR) ensures equitable access to academic resources, demonstrating the versatility and adaptability of AI in various contexts [10].

In short, AI transforms how people with visual impairments interact with and understand the world. While significant progress has already been made, there is still much to explore and improve. The adaptability, accuracy and cultural relevance of these solutions represent current and future challenges in this evolving field.

Some findings of this study are consistent with those of previous research that highlighted the difficulties faced by people with visual impairments when accessing e-learning platforms and digital content. Previous studies have also highlighted the importance of assistive technologies and web accessibility in improving educational outcomes for this demographic. For example, Leporini and Buzzi [25, 44] similarly identified the critical role of accessible design in e-learning environments [41]. However, this study provides a more comprehensive analysis by incorporating specific examples of e-learning platforms, such as Moodle and Teams, and detailing the assistive technologies that can enhance accessibility.

Furthermore, while previous studies have often focused on the theoretical aspects of accessibility, this study provides practical recommendations and specific measures to improve the usability of e-learning platforms [41]. These include suggestions such as keyboard navigation, speech synthesis systems, and compliance with the WCAG, which are crucial for creating inclusive digital learning environments. On the other hand, the study highlights the importance of metrics in assessing web accessibility, which is a less explored area in previous research. By proposing indicators such as the level of the WCAG compliance, the number and type of accessibility errors, and the time and effort required to complete tasks, this study provides a solid framework for evaluating and improving web accessibility [38].

Similarly, previous studies have highlighted the important role of assistive technology in improving the lives of visually impaired individuals. Advances in AI and deep learning techniques for the early diagnosis of eye diseases align with the findings of this study. In addition, the emphasis on the importance of training and sustainable funding in the literature is consistent with the recommendations of this study.

Identified barriers to access, such as cost, lack of training, and limited availability, have also been noted in previous studies. The impact of the COVID-19 pandemic on people with visual impairment, especially in education, has been a recurring theme, reaffirming the need for more inclusive digital environments [37].

The educational and social benefits of assistive technology have been widely recognized. Improved independence and social integration through these tools was a consistent finding, demonstrating the positive impact of assistive technology on the quality of life of people with visual impairment.

The integration of AI into assistive technology, especially in medical diagnostics and daily living aids, has been the subject of numerous studies. Advances in AI techniques, such as CNNs and GANs, for diagnosing eye diseases are consistent with previous research findings, demonstrating the transformative potential of AI in healthcare.

This study builds on the initial work of previous studies and provides a practical roadmap for improving the accessibility of e-learning [39], [40], [41]. This highlights the need for continuous improvement of digital tools and platforms to ensure that visually impaired learners can fully participate in and benefit from online education. The integration of concrete examples, practical recommendations, and evaluation parameters makes this study a valuable resource for educators, developers, and policy makers who wish to promote inclusion in digital education. The findings align with previous research, highlighting the importance of sustainable funding, training, and inclusive digital environments. Advances in deep learning techniques continue to shape healthcare and everyday life, providing unprecedented autonomy and access to information for people with visual impairments. Future research should focus on addressing access barriers and ensuring that technological advances are inclusive and accessible to all [42].

5. Discussion

First, it is believed that the type of content that is currently most affected by limitations is that which contains graphic information, such as images, diagrams, tables, and mathematical formulas. These materials are difficult for visually impaired people to interpret and transmit, especially if they do not have adequate tools to convert them to accessible formats, such as audio or tactile. Moreover, these contents are often essential for technical subjects such as mathematics, physics, and chemistry, which are fundamental for the academic and professional development of visually impaired students [11].

An example of a specific e-learning system that can be mentioned is Moodle, an online learning platform that is widely used at various educational levels. Moodle has some features that favor accessibility, such as the possibility of adjusting font size and contrast, compatibility with screen readers, and the obligation to include alternative text when inserting an image [10]. However, it also has some limitations, such as difficulty in navigating drop-down menus, lack of subtitles in videos, complexity in accessing forums, and incompatibility with certain file formats. These constraints can restrict visually impaired students from gaining access to and engaging in Moodle activities and resources [10].

To improve Moodle accessibility, the following measures can be applied [14]:

- Adding a keyboard navigation option to facilitate scrolling through the page elements;
- Incorporating a speech synthesis system that reads the screen content and provides auditory feedback to the user;
- Offering the option to download content in accessible formats such as PDF, MP3, or Braille;
- Clear and descriptive labels and titles to help organize information and guide users;
- Following the WCAG to ensure that Moodle design and development meet inclusion standards.

In terms of specific commercial assistive technologies that can be used, there are a wide variety of options available [17], [31]:

- *Siri:* a voice-activated virtual assistant that allows users to perform various actions, such as making calls, sending messages, searching for information, and playing music [43]. It is useful for visually impaired people because it allows them to interact with the device without having to see the screen. In addition, it can read the content of the screen and respond to user questions and commands.

- *JAWS:* a screen reader that converts text to speech and allows users to navigate the internet and use Windows applications. JAWS can be useful for visually impaired persons because it allows them to access information and resources independently and efficiently. In addition, JAWS can work with a Braille line, which is a device that displays raised text to be read by touch.

- *Seeing AI:* This application uses AI to recognize and describe objects, people, text, colors, etc. Seeing AI can be useful for visually impaired people because it allows them to better understand its environment and perform everyday tasks. In addition, Seeing AI can scan and read barcodes, documents, banknotes, etc. [33].

In connection with programs such as Teams, which are online communication and collaboration platforms [10], some assistance measures are already included:

- *Narrator:* function that aloud reads the text and on-screen elements, such as buttons, menus, and images. Narrator can be useful for visually impaired individuals, allowing them to navigate through Teams and participate in meetings and chats. In addition, Narrator can adjust the speed, pitch, and volume of the voice, language, and dialect.

- *Magnifying glass:* This function magnifies part of the screen, facilitating the visualization of details. The magnifying glass can be useful for people with low vision because it allows better viewing the contents of the computer and customize the zoom level and display mode. In addition, Lupa can follow the mouse pointer, keyboard, or text.

- *Live captioning:* feature that displays in text what is being said during a meeting or call. In addition, live captioning can be useful for people with hearing impairments by allowing them to follow and participate in conversations. Live subtitles can translate the meeting or call into another language.

Finally, the following metrics are used to detect the usability of a website for people with disabilities [25, 44]:

- *WCAG conformance level:* This measure evaluates the degree to which a web page meets the accessibility criteria established by the WCAG. These criteria are grouped into four principles: perceivable, operable, understandable, and robust. Each principle has a set of guidelines, and each guideline has a set of levels: A, AA, and AAA. The level of conformance to the WCAG can be expressed as a grade (e.g., A, AA, or AAA) or percentage (e.g., 80% compliance with level AA) [22].

- *Number and type of accessibility errors:* This measure identifies and classifies accessibility problems in a web page. These problems can be of different natures, such as code, design, and content errors. The number and type of accessibility errors can be obtained using automatic or manual tools that analyze web pages and generate reports with results [11].

- *Time and effort required to complete a task:* This metric measures the ease and difficulty of performing a specific task on a web page for a visually impaired user. The task can include, for example, searching for information, completing a form, or purchasing a product. The time and effort required to complete a task can be measured using observation or self-reporting techniques, which record the time, steps, difficulties, and user satisfaction [32].

To address these issues, the selection of the research object focused on the most widely used and representative e-learning platforms, such as Moodle and Teams, which are prevalent in educational institutions [41]. These platforms were chosen because of their widespread adoption and significant impact on the educational experiences of visually impaired students. The application of the findings is intended to guide the development of inclusive e-learning environments. By implementing the recommended accessibility measures and leveraging assistive technologies, educators and developers can create a more equitable and effective learning experience for visually impaired students [38]. The results of this study are intended to inform policymakers, educational institutions, and technology developers about the critical need for greater accessibility in digital education and to promote practices that ensure that all students can fully and independently participate in online learning [39].

6. Conclusion

This study revealed that assistive technology has become a fundamental component of support for people with visual impairment, offering tools that significantly improve their quality of life and social participation. It has been identified that although e-learning platforms such as Moodle and Teams present certain accessibility barriers, the implementation of specific assistive technologies can significantly improve accessibility. Furthermore, practical recommendations and evaluation metrics are highlighted as essential elements for developing inclusive digital environments.

The findings of this study align with previous research that highlighted the ongoing challenges faced by people with visual impairments when accessing e-learning platforms and digital content. Previous studies have also demonstrated the importance of assistive technologies and web accessibility in improving educational outcomes for this demographic [38]. This study advances by providing a more detailed analysis of specific platforms and assistive technologies and practical recommendations and evaluation metrics, thus extending the existing theoretical framework with practical and applicable contributions.

This study has important implications for the development and implementation of accessible assistive technologies and e-learning platforms. The results underscore the need for clear policies and collaborative efforts to overcome economic, cultural, and implementation barriers to full inclusion. This study also highlights the importance of training and education in the use of these technologies for both users and practitioners as a determining factor in maximizing their positive impact.

A holistic approach combining technology, social support, education, and community is recommended to effectively address the challenges associated with visual impairment. Future research should focus on developing and evaluating more accessible assistive technologies and e-learning platforms and exploring strategies to overcome implementation and training barriers. In addition, it would be beneficial to investigate the long-term impact of these technologies on the quality of life and social inclusion of people with visual impairments. With effort, innovation, and collaboration, it is possible to move toward a more inclusive and equitable future.

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References

[1] JOHNSON L., BECKER S. A., CUMMINS M., ESTRADA V., FREEMAN A., and HALL C. *NMC Horizon Report: 2016 Higher Education Edition.* The New Media Consortium, Austin, Texas, 2016. https://www.learntechlib.org/p/171478

[2] BULUS C. *Social construction of technology: web accessibility in people with visual disabilities*. Thesis, National University of La Plata, 2021.

[3] DUSSEL I., & QUEVEDO L. A. *Education and new technologies: the pedagogical challenges in the digital world.* Santillana, Buenos Aires, 2010.

[4] CONTRERAS B. P. U., & OYOLA L. T. *National Administrative Department of Statistics - DANE*, n.d.

[5] LOPEZ R. A. Communication barriers of people with visual disabilities from a social approach. *Journal of Social Communication*, 2022, 49-73.

[6] MTEBE J. S., & RAPHAEL C. Key factors in learners' satisfaction with the e-learning system at the University of Dar es Salaam, Tanzania. *Australasian Journal of Educational Technology,* 2018, 34(4): 107-122. https://doi.org/10.14742/ajet.2993

[7] MORIÑA A. *Theory and practice of inclusive education.* Aljibe, Málaga, 2004.

[8] LUGO I. M., NARVÁEZ C. M., and RIVERO K. C. Development of accessible virtual learning experiences. Attention to the needs of people with visual disabilities. *EDUTEC: Electronic magazine of educational technology,* 2017, 34-47.

[9] LOBLE L. *Learning to live in the time of AI.* UNESCO, 2018. https://www.unesco.org/en/articles/learning-live-time-ai-1

[10] ALMURAYZIQ T. S., ALSHAMMARI G. K., ALSHAMMARI A., ALSAFFAR M., and ALJALOUD S. Evaluating AI Techniques for Blind Students Using Voice-Activated Personal Assistants. *International Journal of Computer Science and Network Security,* 2022, 22(1): 61–68. https://doi.org/10.22937/IJCSNS.2022.22.1.10

[11] LIU W., YU W., LI K., ZHOU S., WANG Q., and YU H. Enhancing blind-dumb assistance through a self-powered tactile sensor-based Braille typing system. *Nano Energy,* 2023, 116: 108795. https://doi.org/10.1016/j.nanoen.2023.108795

[12] MESA A. A. A. A., & SALAZAR R. D. Mobility assistance devices in people with visual disabilities: a bibliographic review. *Polytechnic Magazine,* 2019, 107-116.

[13] ZAMORA LOOR G., ÁLVAREZ URIBE Y., SOLANO GALARZA M., and DURÁN OSPINA P. TIFLOUTM virtual platform for E-learning based on Typhlology tools for students with visual disabilities at the Technical University of Manabí. *Revista Arbitrada Interdisciplinaria De Ciencias De La Salud. Salud Y Vida*, 2019, 3(6): 169-185. https://doi.org/10.35381/s.v.v3i6.314

[14] DAVILA E. S., & HERRERA S. D. Inclusive Higher Education: An Approach to Assisted Classroom Design. *Pedagogical Horizons,* 2015, 17(1): 104-117.

[15] CORREA-TORRES S. M., & MUTHUKUMARAN A. Impact of COVID-19 on services for students with visual impairment: Experiences and lessons from the field. *British Journal of Visual Impairment,* 2023, 41(4): 876–886. https://doi.org/10.1177/02646196221109082

[16] AMPONSAH S., & BEKELE T. A. Exploring strategies for including visually impaired students in online learning. *Education and Information Technologies*, 2023, 28(8): 9355–9377. https://doi.org/10.1007/s10639-022-11145-x

[17] CANDIA GARCÍA F. Design of a curricular e-learning model, using an active and participatory methodology. *Revista Iberoamericana para la Investigación y el Desarrollo Educativo,* 2016, 7(13): 147-182. https://doi.org/10.23913/ride.v7i13.240

[18] MATOUŠEK J., KRŇOUL Z., CAMPR M., ZAJÍC Z., HANZLÍČEK Z., GRŮBER M., and KOCUROVÁ M. Speech and web-based technology to enhance education for pupils with visual impairment. *Journal on Multimodal User Interfaces,* 2020, 14(2): 219–230. https://doi.org/10.1007/s12193-020-00323-1

[19] JIMÉNEZ L., & CARRIÓN J. *Inclusive education: Opening doors to the future.* Almeria University, 2019.
[20] KISANGA S. E., & KISANGA D. H. The role of assistive technology devices in fostering the participation and learning of students with visual impairment in higher education institutions in Tanzania. *Disability and Rehabilitation: Assistive Technology,* 2022, 17(7): 791–800. https://doi.org/10.1080/17483107.2020.1817989
[21] KLINGENBERG O. G., HOLKESVIK A. H., and AUGESTAD L. B. Digital learning in mathematics for students with severe visual impairment: A systematic review. *British Journal of Visual Impairment,* 2020, 38(1): 38–57. https://doi.org/10.1177/0264619619876975
[22] LAFUENTE G. J., BALLESTEROS C. A., and FILIPPI J. L. Desarrollo de una plataforma de capacitación a distancia utilizable y abierta para personas con discapacidad visual. Proceedings of the XX Workshop de Investigadores en Ciencias de la Computación, 2018, pp. 1227-1231. http://sedici.unlp.edu.ar/handle/10915/68685
[23] PARIDA M., & SINHA M. Pandemic and disability: Challenges faced and role of technology. *Technology and Disability,* 2021, 33(4): 245–252. https://doi.org/10.3233/TAD-200311
[24] MORASH V. S., & SIU Y. T. Social Predictors of Assistive Technology Proficiency among Teachers of Students with Visual Impairments. *ACM Transactions on Accessible Computing,* 2017, 9(2): 1–27. https://doi.org/10.1145/2999569
[25] LEPORINI B., & BUZZI M. Learning by e-Learning: Breaking Down Barriers and Creating Opportunities for the Visually-Impaired. In: STEPHANIDIS C. (ed.) *Universal Access in Human-Computer Interaction. Applications and Services.* Springer, Berlin, Heidelberg, 2007: 687–696. https://doi.org/10.1007/978-3-540-73283-9_75
[26] OTHAMNI B., CACHEIRO GONZÁLEZ M. L., RODRIGO SAN JUAN C., and LORENZO PÉREZ V. A. Accessibility of the distance education model for students with visual disabilities. *Journal of Inclusive Education,* 2018, 11(1): 25-38.
[27] SARICA A. D., ULU-ERCAN E., and COŞKUN U. H. COVID-19 and Turkish University Students with Visual Impairments: An In-Depth Inquiry. *Journal of Visual Impairment & Blindness,* 2022, 116(6): 817–829. https://doi.org/10.1177/0145482X221144054
[28] DELGADO VÁZQUEZ Á., VÁZQUEZ-CANO E., BELANDO MONTORO M. R., and LÓPEZ MENESES E. Análisis bibliométrico del impacto de la investigación educativa en diversidad funcional y competencia digital: Web of Science y Scopus. *Aula Abierta,* 2019, 48(2): 147–156. https://doi.org/10.17811/rifie.48.2.2019.147-156
[29] PÉREZ IBARRA M., PÉREZ OTERO N., TARIFA H., BOSSOLASCO M. L., QUISPE G., and MEJÍAS M. Entornos virtuales de aprendizaje para personas con discapacidad visual. Proceedings of the XVI Workshop de Investigadores en Ciencias de la Computación, 2014, pp. 1084-1089. http://sedici.unlp.edu.ar/handle/10915/43875
[30] SARACCHINI R., CATALINA-ORTEGA C., and BORDONI L. A mobile augmented reality assistive technology for the elderly. *Comunicar,* 2015, 23(45): 65–74. https://doi.org/10.3916/C45-2015-07
[31] SORRELL M., NORTON D., MCADAMS J., WINTERLING R., and DIPPLE K. Creating an Online Scientific Art Exhibit Formatted for People with a Visual Impairment. *Journal of Web Librarianship,* 2017, 11(2): 105–123. https://doi.org/10.1080/19322909.2017.1300788
[32] SIRIKITSATHIAN P., CHAVEESUK S., and SATHITWIRIYAWONG C. A conceptual framework for better understanding of factors influencing accessibility to a website and its acceptance by university students with visual impairments. Proceedings of the 9th International Conference on Information Technology and Electrical Engineering, Phuket, 2017, pp. 1–5. https://doi.org/10.1109/ICITEED.2017.8250493
[33] ROMERO M. Á., CHÁVEZ T. H., and FIGUEROA R. O. Application of artificial intelligence tools in legal education: considerations about their effectiveness, limitations and challenges. *Latin American Researchers Network,* 2023, 673-678.
[34] ELIZONDO S. *Inclusion and visual disability: Manual for the socio-educational inclusion of students with total and low blindness through the use of ICTs.* Independent Publishing, 2019.
[35] GANASCIA J.-G. *Artificial intelligence: between myth and reality.* UNESCO, 2018. https://courier.unesco.org/en/articles/artificial-intelligence-between-myth-and-reality
[36] FELIX S. M., KUMAR S., and VEERAMUTHU A. A Smart Personal AI Assistant for Visually Impaired People. Proceedings of the 2nd International Conference on Trends in Electronics and Informatics, Tirunelveli, 2018, pp. 1245–1250. https://doi.org/10.1109/ICOEI.2018.8553750
[37] SABORÍO L. C. Covid and its accelerated impact on e-learning and educational technologies. *Logos,* 2022, 3(1): 136-142.
[38] SALAZAR CAZCO S. A., RAMOS VALENCIA M. V., PAREDES REGALADO M. B., and VELASCO ERAZO N. D. R. Web accessibility to students with disabilities in an Ecuadorian university. *AlfaPublicaciones,* 2023, 5(3): 46–67. https://doi.org/10.33262/ap.v5i3.377
[39] SIROKMAN G., BARLOW R., RODRIGUEZ A., CLARK A., and FOGG L. The use of 3D printed media to improve the accessibility of engineering educational materials. Proceedings of the ASEE Annual Conference & Exposition, 2023. https://nemo.asee.org/public/conferences/327/papers/38322/view
[40] SENJAM S. S., MANNA S., and BASCARAN C. Smartphones-Based Assistive Technology: Accessibility Features and Apps for People with Visual Impairment, and its Usage, Challenges, and Usability Testing. *Clinical Optometry,* 2021, 13: 311–322. https://doi.org/10.2147/OPTO.S336361
[41] SALAZAR SANCHEZ M. E., ENRIQUEZ CUADRO A. C., and GUEVARA ESPINOZA J. C. Tics e-Learning and the Social Impact on Higher Education. *Opuntia Brava,* 2020, 12(3): 53-61. https://opuntiabrava.ult.edu.cu/index.php/opuntiabrava/article/view/1048
[42] RAYMOND V. H., AGUIRRE G. V., and TUTIVÉN I. E. *Analysis of the use of technological devices in young people in the Province of Guayas*. University of Seville, 2018: 199-212.
[43] CASTAÑEDA A. G., MORALES C. R., and AGUILAR C. V. *Impact of Virtual Education on Undergraduate Careers in the Area of Health Sciences. A Vision of Technologies in Education.* Cooperative University of Colombia, Bogotá, 2019.
[44] BARRERA Y. C., VÁSQUEZ M. G., and GONZÁLEZ

R. A. EAW: Evaluator of Web Accessibility Criteria for Visual Impairment and Guidelines Related to Motor Disability. *Venezuelan Computer Magazine*, 2017, 12-20.
[45] AMAZON WEB SERVICES. *Clases de almacenamiento de Amazon S3*, 2023. https://aws.amazon.com/es/s3/storage-classes/

参考文:

[1] JOHNSON L.、BECKER S. A.、CUMMINS M.、ESTRADA V.、FREEMAN A. 和 HALL C. 新麦基诺地平线报告：2016 年高等教育版。新媒体联盟，德克萨斯州奥斯汀，2016 年。https://www.learntechlib.org/p/171478
[2] BULUS C. 技术的社会建构：视障人士的网络可访问性。论文，拉普拉塔国立大学，2021 年。
[3] DUSSEL I. 和 QUEVEDO L. A. 教育与新技术：数字世界中的教学挑战。桑蒂利亚纳，布宜诺斯艾利斯，2010 年。
[4] CONTRERAS B. P. U. 和 OYOLA L. T. 国家统计行政部-丹麦，无日期。
[5] LOPEZ R. A. 从社会角度看视障人士的沟通障碍。社会传播杂志，2022，49-73。
[6] MTEBE J. S.，& RAPHAEL C. 坦桑尼亚达累斯萨拉姆大学电子学习系统学习者满意度的关键因素。澳大利亚教育技术杂志，2018，34(4)：107-122。https://doi.org/10.14742/ajet.2993
[7] MORIÑA A. 包容性教育的理论与实践。阿尔吉贝，马拉加，2004 年。
[8] LUGO I. M.、NARVÁEZ C. M. 和 RIVERO K. C. 无障碍虚拟学习体验的开发。关注视障人士的需求。教育技术与培训中心：教育技术电子杂志，2017 年，34-47。
[9] LOBLE L. 学会在人工智能时代生活。联合国教科文组织，2018 年。https://www.unesco.org/en/articles/learning-live-time-ai-1
[10] ALMURAYZIQ T. S.、ALSHAMMARI G. K.、ALSHAMMARI A.、ALSAFFAR M. 和 ALJALOUD S. 使用语音激活个人助理评估针对盲人学生的人工智能技术。国际计算机科学与网络安全杂志，2022 年，22(1)：61–68。https://doi.org/10.22937/IJCSNS.2022.22.1.10
[11] 刘伟、余伟、李凯、周胜、王倩、余华。通过自供电触觉传感器盲文打字系统增强盲人辅助。纳米能源，2023 年，116：108795。https://doi.org/10.1016/j.nanoen.2023.108795
[12] MESA A. A. A. A. 和 SALAZAR R. D. 视障人士的移动辅助设备：书目综述。理工杂志，2019 年，107-116。
[13] ZAMORA LOOR G.、ÁLVAREZ URIBE Y.、SOLANO GALARZA M. 和 DURÁN OSPINA P. 蒂芙露电子学习虚拟平台，基于类型学工具，为马纳比技术大学视障学生提供服务。健康科学跨学科修订杂志。健康与生活，2019, 3(6): 169-185。https://doi.org/10.35381/s.v.v3i6.314
[14] DAVILA E. S., & HERRERA S. D. 包容性高等教育：辅助课堂设计的方法。教育视野，2015，17(1)：104-117。
[15] CORREA-TORRES S. M. 和 MUTHUKUMARAN A. 新冠肺炎对视障学生服务的影响：现场经验和教训。英国视觉障碍杂志，2023 年，41(4)：876–886。https://doi.org/10.1177/02646196221109082
[16] AMPONSAH S. 和 BEKELE T. A. 探索将视障学生纳入在线学习的策略。教育与信息技术，2023 年，28(8)：9355–9377。https://doi.org/10.1007/s10639-022-11145-x
[17] CANDIA GARCÍA F. 设计课程电子学习模型，采用主动和参与式方法。伊比利亚美洲研究与教育发展杂志，2016，7(13)：147-182。https://doi.org/10.23913/ride.v7i13.240
[18] MATOUŠEK J.、KRŇOUL Z.、CAMPR M.、ZAJÍC Z.、HANZLÍČEK Z.、GRŮBER M. 和 KOCUROVÁ M. 语音和基于网络的技术，以加强对视力障碍学生的教育。多模式用户界面杂志，2020，14(2)：219–230。https://doi.org/10.1007/s12193-020-00323-1
[19] JIMÉNEZ L. 和 CARRIÓN J. 包容性教育：打开未来之门。阿尔梅里亚大学，2019 年。
[20] KISANGA S. E. 和 KISANGA D. H. 辅助技术设备在促进坦桑尼亚高等教育机构视障学生参与和学习方面的作用。残疾与康复：辅助技术，2022 年，17(7)：791–800。https://doi.org/10.1080/17483107.2020.1817989
[21] KLINGENBERG O. G.、HOLKESVIK A. H. 和 AUGESTAD L. B. 严重视力障碍学生的数学数字学习：系统评价。英国视觉障碍杂志，2020，38(1)：38–57。https://doi.org/10.1177/0264619619876975
[22] LAFUENTE G. J.、BALLESTEROS C. A. 和 FILIPPI J. L. 发展开发了一个平台，可用于远离视觉障碍的角色。XX 计算科学研究人员研讨会论文集，2018 年，第 1227-1231 页。http://sedici.unlp.edu.ar/handle/10915/68685
[23] PARIDA M.，& SINHA M. 疫情与残疾：面临的挑战和技术的作用。《技术与残疾》，2021 年，33(4)：245–252。https://doi.org/10.3233/TAD-200311
[24] MORASH V. S. 和 SIU Y. T. 视障学生教师辅助技术熟练程度的社会预测因素。计算机协会无障碍计算交易，2017 年，9(2)：1-27。https://doi.org/10.1145/2999569
[25] LEPORINI B. 和 BUZZI M. 通过电子学习学习：打破障碍，为视障人士创造机会。在：STEPHANIDIS C.（编辑）人机交互中的通用访问。应用和服务。施普林格，柏林，海德堡，2007 年：687-696。https://doi.org/10.1007/978-3-540-73283-9_75
[26] OTHAMNI B.、CACHEIRO GONZÁLEZ M. L.、RODRIGO SAN JUAN C. 和 LORENZO PÉREZ V. A. 远程教育模式对视障学生的可及性。《包容性教育杂志》，2018 年，11(1)：25-38。
[27] SARICA A. D.、ULU-ERCAN E. 和 COŞKUN U. H. 新冠肺炎与土耳其视障大学生：深入调查。《视觉障碍与失明杂志》，2022 年，116(6)：817–829。https://doi.org/10.1177/0145482X221144054
[28] DELGADO VÁZQUEZ Á.、VÁZQUEZ-CANO E.、BELANDO MONTORO M. R. 和 LÓPEZ MENESES E. 多样化功能和能力教育影响的文献分析：科学网和斯高帕斯。奥拉·阿贝尔塔，2019，48(2)：147–156。https://doi.org/10.17811/rifie.48.2.2019.147-156
[29] PÉREZ IBARRA M.、PÉREZ OTERO N.、TARIFA H.、BOSSOLASCO M. L.、QUISPE G. 和 MEJÍAS M. 视觉视觉上的人物虚拟体验。第十六届计算科学研究研讨

会论文集，2014 年，第 1084-1089 页。http://sedici.unlp.edu.ar/handle/10915/43875

[30] SARACCHINI R.、CATALINA-ORTEGA C. 和 BORDONI L. 针对老年人的移动增强现实辅助技术。科穆尼卡，2015，23(45)：65–74。https://doi.org/10.3916/C45-2015-07

[31] SORRELL M.、NORTON D.、MCADAMS J.、WINTERLING R. 和 DIPPLE K. 创建适合视障人士的在线科学艺术展览。网络图书馆学杂志，2017，11(2)：105–123。https://doi.org/10.1080/19322909.2017.1300788

[32] SIRIKITSATHIAN P.、CHAVEESUK S. 和 SATHITWIRIYAWONG C. 一个概念框架，用于更好地理解影响网站可访问性和视障大学生接受度的因素。第九届信息技术与电气工程国际会议论文集，普吉岛，2017 年，第 1-5 页。https://doi.org/10.1109/ICITEED.2017.8250493

[33] ROMERO M. Á.、CHÁVEZ T. H. 和 FIGUEROA R. O. 人工智能工具在法律教育中的应用：关于其有效性、局限性和挑战的考虑。拉丁美洲研究人员网络，2023 年，673-678。

[34] ELIZONDO S. 包容和视力障碍：通过使用信息通信技术对完全和低度失明学生进行社会教育包容的手册。独立出版，2019 年。

[35] GANASCIA J.-G. 人工智能：介于神话与现实之间。联合国教科文组织，2018 年。https://courier.unesco.org/en/articles/artificial-intelligence-between-myth-and-reality

[36] FELIX S. M.、KUMAR S. 和 VEERAMUTHU A. 为视障人士打造的智能个人人工智能助理。第二届电子和信息学趋势国际会议论文集，蒂鲁内尔维利，2018 年，第 1245-1250 页。https://doi.org/10.1109/ICOEI.2018.8553750

[37] SABORÍO L. C. 冠状病毒及其对电子学习和教育技术的加速影响。徽标，2022 年，3(1)：136-142。

[38] SALAZAR CAZCO S. A.、RAMOS VALENCIA M. V.、PAREDES REGALADO M. B. 和 VELASCO ERAZO N. D. R. 厄瓜多尔大学残疾学生的网络无障碍服务。阿尔法出版社，2023 年，5(3)：46–67。https://doi.org/10.33262/ap.v5i3.377

[39] SIROKMAN G.、BARLOW R.、RODRIGUEZ A.、CLARK A. 和 FOGG L. 使用 3 德打印媒体提高工程教育材料的可访问性。东南欧年度会议和博览会论文集，2023 年。https://nemo.asee.org/public/conferences/327/papers/38322/view

[40] SENJAM S. S.、MANNA S. 和 BASCARAN C. 基于智能手机的辅助技术：视障人士的辅助功能和应用程序，以及其使用、挑战和可用性测试。临床验光学，2021 年，13：311–322。https://doi.org/10.2147/OPTO.S336361

[41] SALAZAR SANCHEZ M. E.、ENRIQUEZ CUADRO A. C. 和 GUEVARA ESPINOZA J. C. 抽搐电子学习及其对高等教育的社会影响。仙人掌，2020，12(3)：53-61。https://opuntiabrava.ult.edu.cu/index.php/opuntiabrava/article/view/1048

[42] RAYMOND V. H.、AGUIRRE G. V. 和 TUTIVÉN I. E. 分析瓜亚斯省年轻人使用科技设备的情况。塞维利亚大学，2018 年：199-212。

[43] CASTAÑEDA A. G.、MORALES C. R. 和 AGUILAR C. V. 虚拟教育对健康科学领域本科生职业的影响。教育技术愿景。哥伦比亚合作大学，波哥大，2019 年。

[44] BARRERA Y. C.、VÁSQUEZ M. G. 和 GONZÁLEZ R. A. 东亚武器：视觉障碍网络可访问性标准评估员和运动障碍相关指南。委内瑞拉计算机杂志，2017 年，12-20。

[45] 亚马逊网络服务。亚马逊年代 3 存储类别，2023 年。https://aws.amazon.com/es/s3/storage-classes/