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The use of artificial intelligence in the education of people with visual impairment

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Abstract

Over the past decades, technological advances have led to the development of assistive technologies in the field of education. Specifically, in special education, access for people with a disability may require adaptations to educational programs and technological applications to enhance their independence and participation in society. One of these innovative educational technologies is artificial intelligence. Research has shown that the effective application of artificial intelligence is an important aid in the education of students with special educational needs, such as those with visual impairments. This article presents a brief review of recent studies on the application of AI in the education of people with visual impairments and whether it can contribute to improving their quality of life and their equal access to all levels of education. It also provides a case study, the "PeopleLens" system, for an in-depth analysis of the use of AI as an assistive technology.

Keywords: Visual impairment; Education and Assistive Technologies; Artificial intelligence; Special education; Visual impairment

1 Introduction

As an introduction, we emphasize the significance the new Era in Education with the use of Epistemology, along with STEM, Robotics, Games, Virtual Reality and other emerging technologies, that has open new views and approximations to the educational practices including assessment, intervention and inclusion for all, which is very effective and productive and facilitates and improves the assessment, the intervention, and the educational procedures via mobile devices that bring educational activities anywhere [70-71], various ICTs applications that are the main supporters of education [72], and AI, STEM, Games and ROBOTICS that raise educational procedures to new performance levers [73-78]. Additionally, the improvement and blending of ICTs with theories and models of metacognition, mindfulness, meditation, and emotional intelligence cultivation [79-82], as well as with the use of Epistemology and science education, [83-90], accelerates and improves the educational practices and results, especially in children with visual impairments.

Vision is one of the most important communication channels for humans, since 80% of all information received on a daily basis passes through the visual system (Chia et al., 2004; Buchberger, 2004; Wolbers & Hegarty, 2010). Consequently, its absence implies numerous cognitive, socio-emotional, and motor problems that greatly impact daily life and, in general, the quality of life of individuals (Sonksen, 1997).

According to World Health Organization data, approximately 2.2 billion people are visually impaired. Of these, about 24.5 million are schoolchildren (Bourne et al., 2018), and it is estimated that this number will increase in the future due to population growth. Therefore, there is a strong need to provide effective assistance to visually impaired students, as access to education is crucial for lifelong learning and overall progress (Manjari, 2020).

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However, these children and their families still face difficulties in accessing educational services and obtaining basic learning materials (WHO, 2020). It is therefore necessary to conduct school-based interventions to address the problems that affect the quality of education of people with visual impairments. These interventions should support communication, social-emotional skills, motor skills, cognitive skills, and orientation and mobility (Stearns, 2017). The implementation of interventions may vary to meet the needs of children by individualizing teaching methods (Wiley et al., 2016).

Assistive technology aims to provide this assistance. It includes tools that enable people with visual impairments to access education by supporting their functioning (Yuan & Folmer, 2008; Cook et al., 2007). Additionally, it benefits students both on a learning and social-emotional level (Luk, 2005).

Rapidly evolving AI technologies are also considered assistive technologies. They create the potential for new types of interactions between humans and AI, greatly facilitating many aspects of the daily lives of people with visual impairments, such as their education, while enhancing their autonomy and self-confidence (Grue et al., 2009).

According to Patterson (1990), Artificial Intelligence, as a branch of Computer Science, involves the study and creation of computer systems that demonstrate some form of intelligence. These systems learn new concepts, can reason and draw useful conclusions about the world around us, understand natural language or a visual scene, and perform other feats that require human-like intelligence. They include characteristics such as thinking, knowing, planning, learning, communicating, perceiving, and the ability to move and manipulate objects (Russell & Norvig, 2003).

Representative AI technologies that support and facilitate learning processes and improve the daily functioning of people with blindness and other severe visual impairments include smart mobile phones with cameras and AI algorithms, various wearable systems, and robotics (Lanigan et al., 2006; Lopez-de-Ipina et al., 2011; Kulyukin et al., 2005). In addition, there are several applications based on mobile phone cameras, artificial intelligence algorithms, and audio (Avila et al., 2016; Hoonlor et al., 2015; Morrison et al., 2021).

This article focuses on the most representative technologies, highlighting how they contribute to the educational process and the quality of life of people with visual disabilities in general. It also presents one of them in detail as a case study.

2 Assistive AI technologies for people with visual impairments

An example of a device that harnesses computer vision and benefits people with visual disabilities is "smart" glasses, which can extract and recognize text from an image and convert it into speech. In this way, they help blind or visually impaired students "read" images. Text is detected using OpenCV software and Tesseract, Efficient and Accurate Scene Text Detector (EAST), and Visual Character Recognition (OCR) tools based on Deep Learning techniques. The recognized text is further processed through Google's Text to Speech and converted into an audio signal for the user (AlSaid et al., 2019).

In previous years, an experimental system designed to acoustically represent images by converting them into sounds was presented. It was a step towards developing a vision replacement system for blind people (Meijer, 1992). Proulx (2010) discussed sensory substitution devices that convert images into sound. Another research (Patel et al., 2012) involved a device that converted images into sound and was placed on 13 blind people. After locating visual stimuli (LEDs and objects), it allowed them to learn where something was located by listening to it.

There are also several assistive applications that use mobile phone cameras and sound to help people with visual impairments recognize objects. For example, VisualPal is a mobile app for visually impaired people. It uses Artificial Neural Network Technology along with Euclidean Distance measures. This technology allows VisualPal to detect the direction of maximum brightness and main colors in the image and classify video frames into different categories based on previous frames. This application of artificial intelligence contributes to VisualPal's functionality, making it capable of recognizing objects and providing responses based on stored information (Bagwan & Sankpal, 2015).

Another typical application is TapTapSee, which uses AI algorithms to recognize objects and environments such as animals, colors, plants, and texts. By taking a photo or video with a mobile phone camera, users can recognize objects. Then, the Voice-Over reader provides information through voice messages within seconds (https://taptapseeapp.com/, https://www.aipoly.com/). Among TapTapSee's advantages are its minimal design and ad-free nature, which do not interfere with the app's functionality for users. Another advantage is its highly accurate calculations. However, there are also some problems, such as its reliance on phone accessibility settings, namely VoiceOver for Apple mobile users or TalkBack for Android users, to receive audio information. If users do not have phones with these settings, they cannot easily navigate the phone settings to change the accessibility settings, which can confuse users who need auditory or haptic responses to understand their actions on a smartphone (Awad, 2018).

Similarly, Aipoly Vision is a mobile app developed by V7 Ltd to help people with visual impairments and possibly color blindness to perceive the environment. Users focus their phone's camera on the object of interest and press a button for the type of recognition they wish to perform, thus activating artificial intelligence and informing them via audio. The app can recognize plants, animals, text, coins, food, and colors. Its advantages include integration in multiple languages, allowing users from different parts of the world to use it. It is also equipped with a "smart flashlight" that automatically turns on the phone's flash if the room is dark. Additionally, accessibility settings such as VoiceOver are not required because a speech system is built into the app, activated at the user's request. The disadvantages include the inability to create audio outputs at necessary points or during certain navigation, making it unclear to blind users which interface they are accessing. They also do not know when the application has been successfully launched. Some functions are only accessible to subscribers who incur a monthly fee (Sosa Garcia, 2017).

Another mobile application was developed by Qureshi, Rajbhar, Pisat, and Professor Bhosale (2021). It provides AI-based functions to help blind users. It includes object recognition, acquiring information about the environment, navigation instructions, reading text, and other similar functions through voice commands. When used, the camera acts as a background service to assist the user by continuously processing environmental data and providing information. There is also a button for manual interaction, where data is processed by an algorithm, a response is generated, and the user receives a speech response. The application's short response time makes it useful in real-world situations.

AI is also being exploited in applications that allow users to train machine learning models to recognize specific objects. A recent example is teachable object recognizers, where blind users train their camera-equipped devices, such as mobile phones, to recognize everyday objects using a few photos as examples. This process helps them adapt recognition models according to their needs and preferences. Besides personalization, the interactive nature of these apps is important for another reason. It helps users discover basic concepts of machine learning and become familiar with artificial intelligence, contributing to the larger goal of making this technology accessible to people with disabilities (Hong et al., 2022).

In recent years, AI aids such as Orcam MyEye 1 (a handheld device) and Seeing AI (an iPhone and iPad app) have enabled blind users to convert printed text into voice, whether small passages or whole pages at a time (Granquist et al., 2021).

A similar case is WiYG (Write-it-Yourself Guide), which allows blind users to write on printed documents without the help of others. WiYG uses a 3D printing component that adapts to the mobile phone and artificial intelligence through computer vision algorithms. Specifically, the algorithms process the image captured by the smartphone camera and allow the system to recognize the paper's position and the various fields on it, generating audio navigation instructions (e.g., move left, you are close) to guide the user (Feiz et al., 2019).

Therefore, the use of Braille, one of the oldest tactile reading and writing systems for blind users, has steadily declined due to advances in digital technologies. This decline is especially seen in speech technology, which allows a computer or device to reproduce text in a document by voice, and in computer vision, which enables computer systems to recognize, analyze, and process images or videos, and Optical Character Recognition (OCR) (NFB, 2016). OCR systems can recognize characters and words in an image and convert them into a text format that computer systems can process or read by speech software (Vázquez & Steinfeld, 2014).

Many independent reading applications have emerged, leveraging these developments. For example, Kurzweil Scanner for desktop computers, KNFB Reader, Seeing AI mentioned above, Text Detective for mobile phones, FingerReader, OrCam, and HandSight (Feiz et al., 2019). Of these tools for the visually impaired, only Seeing AI and KNFB Reader use AI technology. KNFB Reader uses AI to recognize text in printed documents through OCR technology and convert it into an audio format that the user can hear (Dadhich & Dutta, 2018). Users can photograph any text and hear it aloud. However, the application is relatively costly, and the text is read with an automated voice (AbouElwafa et al., 2018).

Envision AI is another mobile app developed to help visually impaired people describe their environment. It uses artificial intelligence and OCR (Optical Character Recognition). This app can detect and recognize various objects such as text, handwriting, colors, and barcodes. The color detection feature can also help people who are color blind. It can recognize faces after being trained to remember them. One weakness of this application is its dependence on TalkBack support. Its interface is well developed, and the functions are clearly described. However, activating TalkBack is a challenging process for people with visual impairments (Khenkar, 2016).

Another smart assistant for blind people is the Blind Reader, which uses AI technologies like image-based text recognition and speech synthesis. Specifically, a text document or a .ppt file is converted into a PDF file by recognizing a collection of words. Since the app is built for Android, it uses predefined APIs to convert text to speech, making the process more efficient. However, the app does not recognize text through an image but uses Google's Vision API for this purpose (Sabab & Ashmafee, 2016).

There are also systems such as TacPic that convert images into Braille. The TacPic system is a web-based platform developed to create tactile educational materials (TEM) for blind and visually impaired people. It allows users to upload images to a website and uses artificial intelligence in cloud computing to create aesthetic educational materials based on these images. In short, text is converted to Braille and printed in 3D. This system is an innovative solution that allows for individual adaptation and personalization of educational materials for people with blindness or visual impairments (See & Advincula, 2021).

Another model based on artificial intelligence facilitates the needs of blind students by allowing them to easily submit requests and assignments to academic services. This model ensures that all students have equal opportunities to access academic materials and submit requests. It consists of four phases: a) voice recognition using Apple's Siri and Amazon's Alexa digital assistants, with words or sentences entered into the system; b) text from voice recognition is processed, and keywords are extracted through an AI system; c) requests are categorized by classification methods with AI assistance; and d) the student's request is addressed. However, the system's inability to ensure consistency between requested and provided services can challenge its effectiveness and reliability (Almurayziq et al., 2022).

In 2020, Agrawal, Agrawal, and Padiya developed a similar system with a voice recognition mechanism for multiple-choice exams. This system posed questions, administered questionnaires, recorded answers via microphone, and corrected them if the examinee changed their mind, helping to make exams smoother for blind students.

For younger students, an important supporting app designed by experts in the education of visually impaired students at the University of Arizona and developed by the RNIB (Royal National Institute of Blind People) is "Animal Watch." Researchers Beal and Rosenblum (2015) developed this assistive technology application using AI algorithms to enhance the mathematical abilities of visually impaired students, focusing on solving verbal problems. It is used in combination with Braille materials and accessible graphics in real educational environments. The app includes games, challenges, and educational content adapted for visually impaired people related to environmental, nature, and wildlife issues. It aims to enhance their mathematical knowledge, solve verbal math problems, and encourage them to explore the world of animals and nature, providing an enjoyable educational experience. The app was tested on students with moderate and severe visual impairments, and the results were encouraging. Students found it fun, improved their math skills, and worked without being fully dependent on the teacher to solve problems (Beal & Rosenblum, 2018).

Another application is the Phantom Haptic Device, a high-definition, six-degree-of-freedom (DOF) desktop haptic device. It uses AI to develop and improve control and feedback algorithms, allowing users to interact with virtual objects naturally. The user, through a controllable and connected arm, feels the textures and shapes of virtual objects with high realism, as these algorithms transfer sensations from the computer to the user based on their movements and interactions. Phantom enables learners to feel an object from all sides (Brewster, 2005). Thus, they receive information about its geometric structure, which can be tactilely sensed, and they can touch rare objects they otherwise would not (Fischer & Vanche, 2003).

Beyond teaching or supporting examinations, new AI technologies can offer children with blindness opportunities to explore concepts and cultivate skills, like social skills often learned through vision. The PeopleLens program uses an augmented reality (AR) device combined with four computer vision algorithms worn on the head. Users perceive information and sounds from their environment, enhancing social interaction and understanding of their social surroundings (Morrison et al., 2021).

3 Analysis of the artificial intelligence system "PeopleLens"

For children born blind, social interaction is a challenge. Therefore, Morrison, Cutrell, Grayson, and Jones (2021) designed PeopleLens to help people with blindness or low vision better understand their immediate social environment by identifying people in space. The system, combined with a program based on research and practices from psychology and speech and language therapy, facilitates interactions for children and young people with visual impairments, helping them forge social relationships with peers.

PeopleLens is a sophisticated prototype AI system using an augmented reality device placed on the child's head, combined with four advanced computer vision algorithms. It continuously detects, recognizes, tracks, and records the gaze directions of people in the area. It then presents this information to the user via spatial audio from the person's direction. It can also recognize and read the names of familiar people when the user looks at them, helping them understand their peers' positions and distances. The sound comes from the person's direction, allowing the user to understand both the relative position and distance of nearby people.

The system uses a series of sounds to help the user mentally place individuals in the surrounding space. A sound indicates when the user's gaze has traversed a person up to 10 meters away. The sound is followed by the person's name if they are registered with the system, are within 4 meters, and both ears of the person are detected. Another sound guides the user to find and center the face of a detected person for 1 second, even if not recognized, and adjusts the tone to help the user align their gaze accordingly. Unregistered individuals are recognized with a click sound, and an audio alert informs the user when looking at someone. In the school environment, the system is helpful as a visually impaired student can create a mental map of the people around them, identifying recognized classmates, allowing interaction. This replaces eye contact, which typically signals the start of interaction.

The recognition of individuals and their identification is achieved by taking photographs and processing them with computer vision algorithms. A person registers by taking multiple photos with the phone connected to PeopleLens. The photos are not stored but are converted into a vector of numbers representing the person, recognized by the algorithms that support the system. Because these vectors differ from those used in other systems, PeopleLens recognition does not lead to recognition by another system. No video or recognition information is recorded, ensuring images cannot be used maliciously.

In conclusion, PeopleLens helps children and young people with visual impairments build friendships. For teachers and parents, it is also a way to boost these children's confidence in social interaction. It gives them the opportunity to realize that they can start or stop a conversation if they choose to, enhancing their autonomy.

4 Discussion

Blindness and visual impairments hinder children's education and development. This literature review aimed to present existing assistive AI technologies, including those that contribute to education and those that improve daily life for students and people with visual impairments. As observed, visually impaired students need AI for developing both academic and non-academic skills, and they can become proficient users of these intelligent systems (Luger & Sellen, 2016).

More specifically, it was found that AI support tools benefit the lives and education of blind and visually impaired students because they promote their interests, support their educational tasks, and facilitate their daily lives and lifelong learning, even though some of these technologies are still in the research phase (Hakobyan et al., 2013). Applications linked to smartphones, like the "Be My Eyes" app, can be easily used by people with visual disabilities (Avila et al., 2016). Other benefits include enhancing their functional skills and talents, contributing to their autonomy and independence, and allowing them to operate these tools on their own. This independence helps boost their self-confidence and develop skills for everyday activities and situations (Alves et al., 2009).

Technologies using artificial intelligence appear to remove various barriers in the environment of people with blindness and visual impairment, making these environments more familiar (Emerson & Anderson, 2018; Beal & Rosenblum, 2018). As a result, their fear and tendency toward social isolation are reduced, leading to a greater sense of life satisfaction (Mulloy et al., 2014).

Regarding education, these technologies contribute to better inclusion by providing visually impaired students with access equivalent to that of sighted peers, including information and the school and university curriculum (Vitello & Mithaug, 2013). Ensuring a flexible learning system addresses their diversity, motivates them, and fosters their cognitive and socio-emotional development (Akpan & Beard, 2014). At the same time, students benefit from enriched environments and more engaging educational experiences (Hong et al., 2022). As a result, their personal learning and skills, such as reading and writing, improve, concentration increases, and they become more familiar with modern technology. This leads to enhanced satisfaction from learning, fostering independent learners with a positive self-concept and confidence, reflected in their academic achievements (Emerson & Anderson, 2018).

However, despite the benefits of advances in AI technologies, limitations still hinder the opportunities available to these individuals. For example, their impact is often limited by the high cost of equipment, lack of awareness about existing assistive technologies (Alper & Raharinirina, 2006), insufficient technical support (Hakobyan et al., 2013), and inadequate training for professionals in the proper use of these technologies (Velasquez, 2010).

Moreover, support tools alone cannot fully resolve the challenges these students face, as their effectiveness in education depends on multiple parameters and factors. Essential factors include selecting appropriate devices and training users effectively (Kumari & Bhatt, 2015). The broader school environment and aligning technologies with individual student needs are also crucial (Dai et al., 2020). Other considerations include training experts to work with these technologies (Abuhammad, 2020), the educational community's attitude towards assistive tools, as traditional methods are still widely favored (Copley & Ziviani, 2007), and political and economic issues (Battistin et al., 2020; Bilyalova et al., 2021).

5 Conclusion

This literature review aimed to present the contribution of assistive technologies in the education of people with visual impairment, leading to several conclusions:

To begin with, assistive AI technology offers possibilities that improve living conditions and the educational process for students with visual disabilities, reducing disparities between them and sighted individuals (Moriña, 2022). AI technologies enable tasks that are challenging for people with visual disabilities due to their specific needs, offering supportive use for these individuals. Therefore, society has an obligation to strive for equal quality of life for all and to maximize the autonomy of those facing such challenges. This requires collaboration among students, teachers, families, and other key stakeholders (Sax et al., 2005).

Additionally, the use of mobile applications that combine camera capabilities with artificial intelligence algorithms is often easier than using dedicated devices and helps solve navigation problems both indoors and outdoors. In contrast, devices, although freeing the user's hands and offering comfort, as highlighted in various surveys (Poggi & Mattoccia, 2016; Suresh et al., 2017), are not always easy to use. The hardware can be bulky, heavy, annoying, or embarrassing because it is not discreet (Chen et al., 2021; Neugebauer et al., 2020).

Research data suggest that most studies approach the autonomy of visually impaired individuals from a medical perspective, focusing on user safety during movement and accessibility to environments. This perspective often overlooks the need to treat these individuals as social beings who participate in communities and need to feel included. Moreover, standardized assessments are frequently applied, which may be inappropriate given the diversity among people with visual impairments. Thus, the evaluation of assistive AI technologies needs broader research (Brulé et al., 2019).

Another challenge is protecting individuals' personal data. While designing technology to meet user needs, desires, and expectations is crucial, and aims to provide effective and acceptable assistive solutions, ethical considerations surrounding the use of these technologies must not be ignored (Mouta et al., 2023).

In the context of artificial intelligence in education (AIED) technology, computer programs or applications acting as virtual agents can perform various functions, such as recognizing patterns, providing advice, and communicating with users to support education and learning. However, while AI-based solutions offer personalized education and support, there are serious concerns about privacy violations and negative emotional impacts. Although students and teachers experience a range of emotions, the design of these digital agents primarily focuses on conveying positive emotions, overlooking complex and non-positive emotions that are also significant (Dobrosovestnova & Hannibal, 2020).

Hudlicka (2016) highlights another concern: interactions with digital agents may threaten the privacy of emotional experiences, potentially triggering or manipulating emotions. Moreover, virtual relationships with these agents can blur the boundaries between reality and fantasy, with psychological implications.

In conclusion, artificial intelligence represents a rapidly developing revolution in many fields, including education (Kalani & Thenmozhi, 2023). However, critical thinking is essential when considering technological advancements, particularly for the pedagogical use of AI in diverse educational settings, such as for people with visual disabilities. It is recommended that future work focuses on developing an adaptable evaluation tool to monitor the impact of these technologies across various contexts.

Compliance with ethical standards

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The Authors proclaim no conflict of interest.

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