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IoT as Assistive Technology: Applications in Education as a Tool for Inclusion

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Abstract

Education based on the Internet of Things (IoEdT) emerges as a new conceptual paradigm to define the use of wireless technology as a collaborative tool in teaching-learning processes. Based on this concept, this study explored the potential of the IoEdT as a response to the problems of social inclusion of students with disabilities. In this way, the applicability of the IoEdT as an assistive technology was examined and the challenges faced in the implementation of this tool in the socio-educational context were analyzed. Therefore, this study aims to analyze whether the use of new technologies can become a propelling subject of inclusive transformation or an obstacle to achieving educational equity. For this, an investigation will be carried out with a quantitative, descriptive, and documentary approach. The work presented, as a result, a sampling of available assistive technologies that use the internet of things in the teaching and communication of people with disabilities and the main challenges faced in the availability of this technology.

Introduction

The relationship between education and technology has been long and complex. In recent years, with the advances developed, there has been a strong demand in the educational sector for technological tools that help teachers to improve the teaching-learning process. And as the integration of technology into educational environments takes place, it becomes essential that academic managers and public policymakers consider the need for the inclusion of students with disabilities in the learning space. As such, this relationship between education, technology, and accessibility has been highlighted as an important part of educational and social inclusion policy.

In this sense, the tools that help students in the activation and implementation of information can also mediate the insertion of students with disabilities in learning environments. So that the use of assistive technologies as a tool for socio-educational inclusion can go beyond mere support devices for carrying out certain tasks. In other words, the implementation of technology in the educational context can create more accessible opportunities for PNE students, thus constituting realities that configure new environments for the construction and production of knowledge, which expand the contours of man's relations with knowledge and that provide the insertion of the student in the social space.

The Internet of Things (IoT) is often discussed because of its functionalities, mainly due to the ability to interconnect physical and virtual objects based on information and communication technologies. The versatility of the features brought by the internet of things allowed its use to be extended to several areas of knowledge, including the area of education. In this way, researchers began to get involved and apply technology more and more as an instrument of socio-educational accessibility. Therefore, the Internet of Things in Education (IoEdT) emerged as an interesting tool in the teaching-learning process, in addition to stimulating advancement in the assistive technology market.

However, although there is no denying the importance of the technological features of the IoEdT, the integration of technology in classrooms for students with disabilities is something sensitive and should be evaluated with caution. The precarious access to assistive technology and the possible unpreparedness of teachers regarding the usability of technology can cause adverse effects. Therefore, provoking questions, which we cannot dissociate from the innovative promises of technology, are necessary for us to understand the problems rooted in exclusion, even in the face of the technological potential of expanding access to education.

Thus, this work seeks to reflect on whether the use of new technologies can become a propelling subject of inclusive transformation or an obstacle to achieving educational equity. Therefore, this work intends to evaluate the applications of the IoEdT in the context of educational accessibility, with the main objective of examining the challenges and opportunities of the Internet of Things in this scenario. For this, the investigation developed has a quantitative, descriptive, and documentary design, where the methodological scope of the research will be divided into two stages. The first focuses on a Patentometric study, which aims to analyze patent information to provide a sampling of the practical applications of the IoEdT as an accessibility tool for students with disabilities. The second focuses on a narrative review, which aims to describe and discuss the state of the art of the challenges faced in the availability and application of the IoEdT as a tool for socio-educational inclusion. In particular, the study is justified by the importance of the potential dynamics of new emerging technologies as instruments for disability justice and social transformation. It is essential to understand, at a time when education is seen as a necessary condition for success, how new technologies will be able to punctuate normative modes of educational practices, in addition to questioning these standardized interrelationships existing between individuals, groups, and institutions, what technology offers and collects, simultaneously.

Contextualization

IoT in Education

With technology increasingly present in our lives, internet connection has become an inevitable part of everyday environments. In this sense and paving the way for the fourth wave of technological innovation, the term “Internet of Things” emerged. IoT is defined as the interconnection of devices through the internet, allowing them to communicate with each other by sending and receiving data. IoT differs from traditional information technologies as it is capable of involving a large number of devices. These interconnected devices interact with each other to collect information and control the environment, thus, IoT changes the way everyday activities are carried out, mainly for our lifestyle.

Since its inception, IoT has been applied in several areas, which include health, environment, home automation, and smart cities. However, as technological innovations affect different sectors in a parallel way, therefore, the expected development in the IoT is felt in the educational field. The application of the Internet of Things in Education – IoEdT, despite being far from reaching its maturity, is seen as a powerful tool for technological innovation, which can reshape the way we teach and learn. The IoEdT's capabilities reaffirm the potential of technological tools in removing barriers to education, both physical, such as geographic coverage, accessibility, and independence; and social, such as language, personal development, and social inclusion. Thus, as the internet of things is seen in educational environments, its conceptual basis, in this new learning paradigm, must consider the effects of new technologies as a way of filling the gaps between the physical and the organization of academic information. As Kurzweil and Baker (2017) believe, educational institutions have taken advantage of the potential of IoT to improve the teaching-learning experience.

For Felicia et al. (2021) IoT technology, at all levels of education, offers a richer and more personalized learning environment, where it is possible to recognize students' learning habits, improve the quality of teaching and ensure a better student experience. In other IoT implementations, there is the ability to collect a greater number of data, information, and knowledge about the student. Thus, with the increase in the volume of information collected, it is possible to make better decisions and holistically improve the entire student learning experience. Therefore, the combination of technology and education has allowed for faster and simpler learning, sometimes focused on the individualization of learning, which has improved the level of knowledge and, of course, the quality of students. In this way, it becomes clear that the use of technology only as a platform for distance learning misses the deepest point of the instrument.

IoT in Learning Environments

Through the interface structure, IoT nodes and devices begin to understand learning bottlenecks and create instant and accurate accommodations for students. The model is composed of three layers, they are: (1) The perception layer, which is the closest level to the physical world and therefore has the function of identifying and collecting information. This layer is composed of sensors, electronic codes, cameras, tags, RFID tags, and GPS, among others. (2) The network layer, which is responsible for transmitting the data obtained in the perception layer to the application layer. This transfer can happen through various technologies such as RFID, NFC, Bluetooth, or ZigBee. (3) The application layer, which stores, processes and analyzes the data received by the perception layer, uses a blended learning approach, where relevant information is extracted - as related to the use of existing pedagogical content - and applied to students from a personalized way.

Analytical data about students and the input/output matrix form an essential part of building personalized learning models. According to Hollier and Zahra (2018), student analysis, access to information, and individualization of learning can increase instructional effectiveness and allow students to be included in the learning cycle. Studies carried out by Farhan et al. (2018) found that the use of IoEdT technology allowed teachers to identify students' attention and emotion levels, allowing the instructor to track student progress and develop personalized improvement strategies. Kiryakova et al (2017), the personalization provided by IoT models can be done automatically through information on the level of knowledge and achievements, the pace of learning, and the specific needs of each student.

Method

Patentometry Procedures

The method used in this work was Patentometry, and the approach was quantitative and exploratory, aiming to obtain more concise and clarifying results of the questions that led to this research. According to Guzman (1999), this method involves the analysis and identification of technological innovations, through patent indicators. Making it possible to understand and monitor the technological trend in the various fields of knowledge and transform its content into important and valuable insights.

Given the above, this work proposes to apply the patent analysis tool to enable the identification and analysis of patents that use the IoT as an assistive technology tool in the inclusion of people with disabilities in education. As well as exemplify how the analysis of data contained in patents can provide relevant information that supports strategic decisions in the policy of social inclusion. For this, this study will use the methodological strategy adopted in the study by Nascimento and Speziali (2020), which defines the procedures and elements of descriptive statistics. Considering this methodology, the monitoring period, the databases, and the hierarchical developments will be defined. For the analysis, the present work will cover the period from 2012 to 2022 and will only use patents that participate in the Patent Cooperation Treaty (PCT), available in the WIPO (World Intellectual Property Organization), specifically, in the database made available on Patentscope.

As criteria for searching, the International Patent Classification (IPC) was used, from which the following were chosen: IPC G09B 21/00 (Teaching or communicating with the blind, deaf or dumb); G09B 02/21 (Devices for writing in Braille); G09B 04/21 (Devices for talking to deaf-blind people) and G09B 06/21 (Devices for teaching lip reading). Furthermore, to restrict the search to the scope of the work, the following descriptors were used throughout the patent text: Internet, Network, and IoT. Boolean operators (AND, OR) were also used to look for different combinations. Finally, in the search field, patents with a single member of the family were limited and the radicalization system was used, which uses the root of the words in searches for patents. Before the analysis, an organization of the extracted data was performed, to eliminate inconsistent or redundant data. After carrying out the searches, the largest depositors, publications' temporality, and patents' domains were analyzed. And only then were the most relevant patents identified for each classification, which will be addressed in this present work.

Results

The analysis of patent domains was carried out based on the International Patent Classification, thus, a total of 166 patent deposits were identified, of which 149 for the classification G09B 21/00; 8 of G09B 21/02; 8 of G09B 04/21, and 1 of G09B 06/21. Due to the relationship between the classifications and the subject addressed, each patent can be identified with more than one CIP code. In this way, it was possible to identify the classifications with greater interaction between the patents listed in the study. Therefore, Table 1 presents the classifications with the greatest interactions and their respective subjects.

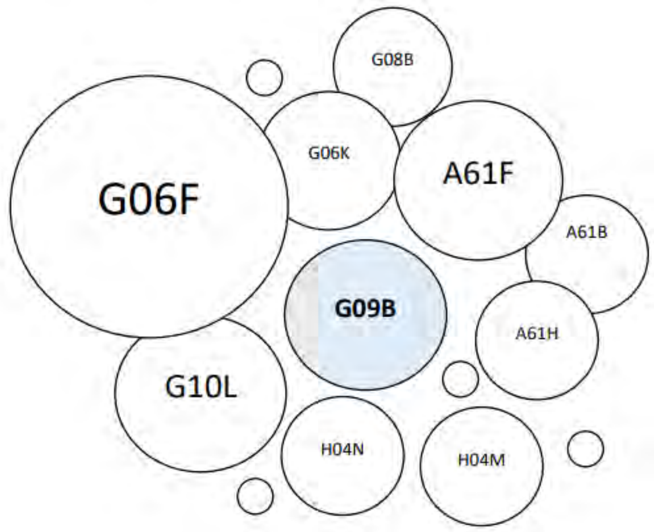


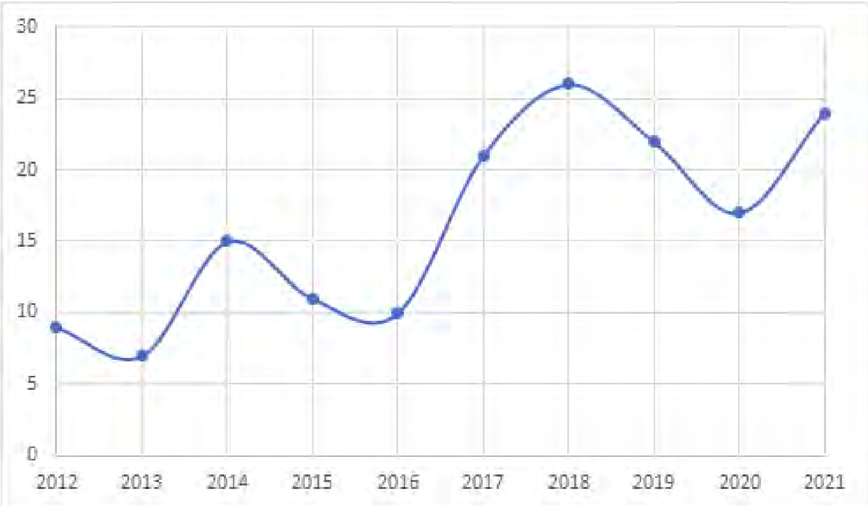
Figure 1. Relationship of Interactions between Study Classifications

Table 1. Relationship of Interactions between Study Classifications

Description	IPC	N° of relationships
Electronic processing of digital data.	G06F	75
Speech analysis or synthesis; Speech recognition; speech and voice processing; Encoding or decoding speech or audio.	G10L	25
Filters implantable in blood vessels; prostheses; devices to prevent the collapse of tubular structures of the body; orthopedic, nursing, or contraceptive devices; promotion; treatment or eye or ear protection; pads, pads or absorbent pads; first aid kits.	A61F	22
Reading graphic data; presentation of data; registration carriers; handling recording carriers.	G06K	18
Telephone communication.	H04M	11
Signaling or calling systems; order telegraphs; alarm systems.	G08B	11
Physiotherapy apparatus, devices for locating or stimulating reflex points in the body; artificial respiration; massage; bath devices for special therapeutic or hygienic purposes or specific parts of the body.	A61H	10
Pictorial communication.	H04N	10
Diagnosis; surgery; identification.	A61B	9
Data processing systems or methods are specially adapted for administrative, commercial, financial, managerial, supervisory, or predictive purposes.	G06Q	2
Card, board, and roulette games; indoor games with small moving game bodies; video games; games not otherwise provided.	A63F	1
Generate or transmit mechanical vibrations in general.	B06B	1
Loudspeakers, microphones, gramophone pick-ups or acoustic electromechanical transducers; aid kits for the deaf; public address systems.	H04R	1

It is observed that the classification of electrical processing of digital data (G06F) was the one that had the greatest interaction with the results proposed by the study. The G06F subcategory deals specifically with data manipulation and processing, so the close relationship is because teaching-learning devices for people with disabilities use communication and information processing technologies, especially IoT technology. The same can be considered in the case of the G06K classification, which covers the reading, transport, and presentation of data and records.

Another important interaction was with the G10L classification, as it receives patents focused on speech synthesis and recognition and audio coding or decoding, which are subjects that are widely discussed in the construction of assistive technologies. In addition, the A61F understands ergonomics. Graph 1 presents the temporal distribution of patents, emphasizing that the period refers to the date of publication in the database, that is, the competent date when the patent becomes public access.



Graph 1. Temporal Distribution of Patents by Publication Date, 2012 – 2021

In the analyzed period, the general average publication rate was 17 patents per year. It is observed that there has been an increase in the number of deposits, with a greater concentration in the last five years, despite the oscillations that are characteristic of documental publication data, as explained by Scartassini et al. (2018). Furthermore, it is worth noting the drops in the numbers of publications in 2015, which accompanied a general decrease in publications in the world (WIPO), and in 2020, which may be related to the Coronavirus pandemic. However, it needs further studies to be properly understood. The analysis identified the largest patent depositors that opted for PCT protection, represented in Table 2. It was chosen to present depositors with three or more patents, of which a total of 9 companies, with this group corresponding to 32.3% of the research corpus.

It appears from the results presented in Table 2 that the depositors are multinational companies, of which six are American companies, one Japanese, one Finnish, and one Israeli. All companies operate in technology sectors, however, only the companies OrCam, Freedom Scientific, and Neosensory operate exclusively in the field of assistive technology. Microsoft is the largest depositor, a multinational company that develops, manufactures, and sells computer software, electronic products, computers, and personal services. Microsoft in recent years has filed patents on assistive technology to improve users' accessibility to its products.

Table 2. Patent Depositors

Depositante	Nº de patentes	%
Microsoft	14	8,7
ORCAM	10	6,2
IBM	9	5,6
Freedom Scientific	4	2,5
Nokia	3	1,9
Sony	3	1,9
Apple	3	1,9
Google	3	1,9
Neosensory	3	1,9
Demais depositaries	109	67,7
Total	161	100,0

Applicability

From the research strategy and the results of the analyzes carried out, it was possible to identify and understand the technological trends aimed at school accessibility for students with disabilities. Thus, this first analysis allowed us to identify the most relevant devices and the role reserved for this technology within the space and school life. Regarding the applicability of assistive technology in the context of educational accessibility, the company OrCam presents some patents focused on devices that help blind or low vision people. Such devices allow visually impaired people to understand texts and identify objects around them through audio feedback. Devices like the Orcam MyEye use interconnected sensors and cameras to identify objects, text, people's faces, and barcodes and convert that information into spoken words.

The projects developed by the University of California present a system to improve color perception in a blind or visually impaired person. The system has two interconnected devices, one of which is a visualization device, which perceives the image and detects the color of the object, and another that produces electromagnetic stimulation in the visually impaired person, which allows, based on an electromagnetic stimulation parameter, the perception of the captured color. Microsoft, among its patents, presents an assistive device for the visually impaired. This device provides an auditory sensory replacement using auxiliary mechanisms of cameras and sensors connected to the internet. In this way, the devices identify the object, and even its location, from the sound vibrations transmitted through the air. Such a tool can help visually impaired people to better understand the world around them, including them in sports activities. Another similar device, presented by the company, is the spatial perception emulator, which uses virtual echolocation, in this case, devices that simulate echolocation are used, allowing the user to navigate in complex environments.

Companies like Sony have registered a system that makes it possible to convert textual parts into Braille codes and non-textual parts into haptic feedback. Both information is gathered and then sent to a device that simulates Braille cells allowing visually impaired people to understand any type of information regardless of their device.

The IoT Bluetooth keyboard, made available by the company Park, is capable of mapping the traditional keyboard and customizing it for each user. The keyboard consists of a Braille key display unit that is used as a smart input device, it can replace traditional keyboards and be connected to any device with Wi-Fi or Bluetooth communication. Google presents a system that translates sounds into two-dimensional patterns of haptic stimulus. Thus, a device to capture a sound signal or certain information is connected via the internet to a tactical graphic reader that is trained to generate a location in a two-dimensional vowel space, which represents the language in Braille.

The Augmentative and Alternative Communication (AAC) system can include individuals suffering from autism, Amyotrophic Lateral Sclerosis (ALS), brain injuries, or strokes in the teaching environment. According to a patent developed by Microsoft, the system interconnects, through network communication, devices that capture gestures, interpret them, and transmit them through a speech generation device. Another technology, developed by Microsoft, is known as the enhanced accessibility system. This technology can identify sign language through cameras and transmit the information to a machine learning model that interprets and translates it into textual and audio formats. Another important technology discusses the use of devices capable of generating audio through text documents. Microsoft introduces a device in which it adjusts the user interface to a focus assist mode. Thus, the device changes the aesthetics of the graphical interface components to allow the user to focus on the most important aspects of the presented content, helping people with attention deficit disorder to focus on the most important aspects presented in the study material.

The company also exhibits a cross-platform system that assists in the accessibility of the user experience. The device that uses IoT to connect various remote devices, captures users' experiences in using smart devices to form a personalized database. With this plurality of metadata, the system customizes a native accessibility experience corresponding to each of the user's events and experiences.

IBM Accessibility Research focuses on developing and improving technologies that remove obstacles and create better experiences for people with disabilities. For this, they use IBM Watson artificial intelligence interconnected with other remote devices to map the trajectory of students with learning disabilities in the face of the proposed tasks and content. From the information collected, it proposes content that can increase the learning quotient. For example, IBM Content Clarifier summarizes, augments, and analyzes text for people with learning disabilities and on the autism spectrum. The IBM Teacher Advisor with Watson applies machine learning to help teachers develop more effective personalized instruction for students with intellectual disabilities, as well as create personalized math modules for people with learning and attention difficulties.

Amazon Lex, artificial intelligence from Amazon, provides tools for solving difficult deep learning problems. Through the availability of the syllabus, Amazon Lex identifies the difficulties presented in completing the content and manages a new routine for the student. Through integration with other services such as Amazon Kendra, which offers a highly accurate intelligent search service based on machine learning; Amazon Polly, which is a service that transforms text into realistic speech and Amazon Lambda for data retrieval, updates, and execution of pedagogical logistics. Such a tool can greatly help students with learning disabilities, analyzing their difficulties and organizing their routines. The use of artificial intelligence by the IoEdT allows the crossing of data to form analyzes of the social network and nodes, which allow for detecting possible learning bottlenecks. Therefore, through the interaction between technology, it becomes possible to obtain new and more complete educational analyses, as well as detect possibilities for generating new knowledge and interactions between students with and without disabilities.

Discussion

IoEdT as an Educational Inclusion Tool

The different limitations resulting from the disability, such as motor limitations, or limitations of communication and language, often end up substantially restricting people's interactions with their environment, generating a posture of retreat and discouragement in the face of everyday situations. In these cases, such difficulties impact the cognitive development and learning of these students, since the social nature of human learning stems from the interaction between people and their environment. According to the concept proposed by Vygotsky (1994), the zone of proximal development is detailed as the distance between the actual level of development, presented through independent problem solving, and the level of potential development, determined through problem-solving under the guidance of capable people. Such a concept highlights the nature of human learning, demonstrating that the assessment of human development should not be summarized only in a real way, but it is important to consider their level of potential development, that is, how individual knowledge is developed and worked together. the interaction of other people and their environment.

In this sense, we can infer that the use of assistive technology can help in the potential development of students with disabilities, being able to facilitate the social interaction of students with special needs and, thus, guide them in solving problems and in their pedagogical development. In addition, it is important to clarify that technological tools do not provide knowledge by themselves, but allow students with disabilities to relate and communicate, which in addition to boosting their potential development, also provides an approximation between individual history and social history. This being true, the integration of technology into educational content in learning environments can provide the necessary support to mitigate the limitations of human interaction and the ability to perceive within the social space. In this sense, the potential of the IoT as assistive technology is highlighted, since this new technology has been presented as a powerful tool for inclusive mediation between people with disabilities and their social interaction in the school environment.

The IoT-based learning model works as a bridge between the physical and virtual world, therefore, it offers a means of reconciling clinical and social approaches to create a model that meets the needs of the individual. According to Seibers (2001), disability can be approached in two ways: Clinical, which portrays disability due to a physical need, in which technology is used to change the human body in a cyborg way; and social, which suggests that disability is created by excluding environmental conditions, that is, the built environment excludes access to people in need. In this way, the IoEdT's technological structure can create a personalized space to alleviate the exclusionary conditions of pre-established environments.

The combination of IoEdT in the inclusive dynamics promotes different pedagogical conceptions, through the availability of tools that configure new environments, build and produce personalized methods, expand the relevance of the social role of schools and remodel the conceptions of the traditional school towards an update of its discourse and its practices, towards a concept of a truly inclusive school. The IoEdT application supports educational information by giving people with disabilities a context for the content they are engaging with (Hollier & Abou-Zahra, 2018). Furthermore, it neutralizes the barriers caused by the disability and contributes to the insertion of the individual into learning and development environments. The use of tools in the classroom provides a communication infrastructure capable of absorbing the revealed needs and shaping the environment to include, once again, the student in the socio-educational space (Bakla, 2019).

In the study carried out by Mohammad Hasani et al. (2018), it was found that from the use of instruction assisted by technological resources, students with ADHD showed deeper learning, in addition to a greater interest in the discipline. In a similar study, Pennington et al. (2021) highlighted that the use of assistive and wireless technologies as a socio-pedagogical strategy for students with some type of disability guarantees significant learning and brings positive measurable educational results. As discussed by Bright (2021), the integration of technology into the educational curriculum, as a way of expanding access for people with disabilities, has largely boosted the potential of IoT as assistive technology. For the author, the use of assistive technology in classrooms allows for a less restrictive learning environment, as it encourages equitable exposure to the educational curriculum.

Kiryakova et al. (2017), highlight that the IoEdT directly affects the teaching-learning process of students with special needs, as it involves the needs of students in real-time. IoEdT devices can accommodate students as their difficulties are assessed, without the need for an intermediary. Therefore, as the IoT expands, so does acceptance and adoption by consumers. In this sense, given that the IoT can help based on human limitations, it can be argued that the IoT is, in principle, a tool with great potential to ensure that people with disabilities can obtain assistance and support quickly. and easy, to result in a trajectory towards the achievement of a better quality of life.

Moreover, as shown by the results, there is a trend in the use of new technologies as a measure to increase the accessibility of students with disabilities in educational institutions. The participation of multinational companies in the assistive technology market can foster research and development of new ideas and devices. Thus, given the existing technological possibilities, the IoEdT application can be extended to assistive technology as a resource capable of reducing socially imposed barriers that limit access, permanence, and effectiveness of the learning process.

Challenges

Just as the benefits of this technology are magnified for people with disabilities, so are the potential risks of exclusion. That is why it is necessary to investigate both sides of the balance to answer the guiding question of this study: what does technology offer and collect, simultaneously? While the IoEdT generates excitement about the technology's potential benefits, training issues for professionals; access to technologies; security and privacy;

and interoperability were highlighted as the biggest challenges faced in the interaction between technology and the educational space.

The issue of pedagogical alignment stands out as one of the main barriers to the integration of technology in classrooms. Knowing that the personal and professional experiences of educators with technology often shape their decision to use it or not as a teaching tool, it makes teachers who have not had contact with the resources or knowledge of technology end up having resistance. In implementing these innovations in the classroom. Consequently, this poor training can shape access and opportunities for students with disabilities.

Studies such as the one by James et al. (2019) show that the reluctant attitudes of unqualified professionals about technological accommodations end up becoming an obstacle in the use of assistive technologies. For Lipka et al. (2020), this reluctance in the transaction of the teaching-learning process of students with disabilities is due to the lack of training by professionals. Therefore, training would provide an epistemological evolution in the thinking of educators.

It is also highlighted that to emerge in less restrictive learning environments, an improvement in access to technology is necessary. While IoT development and access are continually improving, lack of funding is a common barrier. Even when the need for assistive technological support by educational institutions is identified, government funding is impossible. According to a study by Atanga et al. (2019), students with disabilities depend on the support and intervention of educational institutions for access to assistive technology, since the devices are expensive, so funding from the State becomes essential to achieve equity. Therefore, families that cannot afford them are more likely to not have access to technology, so the tool willing to reduce inclusion barriers ends up causing more distance. Security and privacy issues are recurring themes in studies on the challenges of technology, as the collection and storage of personal data raise questions about the protection of this information.

IoT systems, in turn, capture sensitive information from people, especially when the subjects are people with disabilities, as this information can be more sensitive than for the majority of the population. According to Hollier and Zahra (2018), the information captured by technological devices about people with disabilities is sensitive, as it is health data. In addition, particularly in the health area, the commercialization of these data can have highly compromising results.

Finally, interoperability emerges as one of the operational challenges, as there are many connected devices but few connectivity standards. Therefore, this scenario makes it difficult to interact with the range of devices that need interconnection. In this way, it becomes complex to connect a “smart solution” to the devices and get all the results. IoEdT solutions, especially when working with an assistive tool, have a very heterogeneous shop floor, largely due to the complexity of human limitations. This complexity ends up challenging many developers who have to opt for proprietary standards making it harder for custom technologies to provide access to PNE students. Furthermore, the unavailability of specialists and the high cost of initial investment leads to the abandonment of many inventors.

Conclusion

With an innovative concept of connectivity, accessibility, and processing of large volumes of data, the internet of things has gained space in our daily lives. In addition, the benefits proposed by the IoT are beginning to be noticed in several sectors, including education. As new technologies are becoming more and more integrated into the seams of society, it is possible to verify their potential as elements for independence, “empowerment” and school and social inclusion of people with disabilities.

Faced with this reality, this study sought to analyze whether the use of new technologies can become a propelling subject of inclusive transformation or an obstacle to achieving educational equity. Moreover, although we do not doubt that the use of IoEdT can help create more inclusive environments and make the learning process more effective, the challenges faced in the application of technological tools end up preventing and hindering the full participation of people with disabilities in school activities. The IoEdT, therefore, offers a greater possibility for students with disabilities to be included in the education system, as well as providing a better and more personalized learning experience. The ability to analyze information from a variety of different sources and interpret it opens up the scope for configuring physical and digital environments to best meet the needs of PNE learners. Thus, the use of assistive tools advocates a social approach to disability, in which each environment is customized to meet individual needs, rather than being forced to adapt to an inaccessible environment.

However, there are significant challenges that must be addressed before the IoEdT can deliver on its revolutionary promise. Thus, for this potential to be harnessed, many factors must be considered and evolved, including pedagogical alignment, professional training, privacy protection, data security, and guidelines for standardization and interoperability of devices. Despite these challenges, it is important not to lose sight of the benefits that IoEdT can bring. As research and patent development evolve, the role of organizations and government becomes critical in providing industry guidance on the importance of developing inclusive tools. In addition, as IoT solutions become more specialized, it will be possible to further identify the benefits of this technology. Finally, there are many interesting directions in the IoEdt's research as a tool to support the needs of people with disabilities that can still be explored.

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