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Accessibility in online exhibitions of Brazilian science museums and centers: identifying strategies and barriers

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Science museums and exhibitions play a crucial role in formal and non-formal education and in the communication of science. However, access to online science exhibitions is still limited. This exploratory study aims to map and analyze the accessibility of online exhibitions provided by Brazilian science museums and centers during the COVID-19 pandemic. The investigation was based on the 69 Brazilian museums mapped in the *Guide to Accessible Science Centers and Museums of Latin America and the Caribbean*. By combining navigation and keyword searches on these institutions' online communication channels, 101 online exhibitions were identified. We divided the analysis into two phases, descriptive and analytical, for identifying the provision of accessibility strategies and assistive technology resources. Out of the 101, 94 exhibitions, presented at 25 museums, provided at least one accessibility resource. The analysis revealed that 87 exhibitions featured keyboard compatibility, 29 included narration, 13 offered video captions, six provided Brazilian sign language interpretation, five had audio description resources, and two contained alternative text for images. The online exhibitions shared their content through various types of media, which necessitate different assistive resources and accessibility options. When examining the relationship between media and accessibility strategies, we can emphasize that exhibitions featuring a variety of media and assistive resources offer greater potential for accessibility. However, this occurs in a very limited number of exhibitions. This gap in accessibility can affect the opportunities for people with disabilities to access non-formal education, science communication, and culture. While we identified accessible online exhibitions covering various themes and areas of knowledge, as well as a few good practices for inclusion, there is still significant progress to be made. There is a demand for increased accessibility in online exhibitions and for a greater number of museums to offer them. We recognize that this task is challenging, as it requires a multidisciplinary and multi-professional effort.

We propose that accessibility and inclusion be made integral to the planning and execution of new online exhibitions from the outset, as the involvement of professionals and visitors with disabilities in this process will foster a more equitable and inclusive education.

KEYWORDS

accessibility in museums, online exhibitions, assistive technology, accessibility resources, non-formal education, science communication

1 Introduction

Science museums and exhibitions play a crucial role in formal and non-formal education and the communication of scientific knowledge across different groups. They create leisure, learning, and enjoyment spaces, fostering curiosity and engagement in science topics. Moreover, they evoke emotions and provide chances to develop essential learning skills, including logical reasoning, hypothesis creation, observation, and linking new knowledge to past experiences (Ribeiro et al., 2024a; Marinho, 2023; Neves et al., 2021; Norberto Rocha, 2018).

Online museum exhibitions were crucial for these processes during the COVID-19 pandemic in 2020 and 2021 (Ribeiro et al., 2024a; Ribeiro et al., 2024b; Araujo et al., 2023; Cazzanelli et al., 2022; Faria, 2022; Silva, 2021; Neves et al., 2021). They have become a way to access museums and were one of the solutions these institutions found to keep connected with their audiences. By allowing online visits, these exhibitions have the potential to overcome transportation, geographic, and sanitary barriers and benefit the education of diverse audiences, especially children and adults with disabilities.

Museums have had an online presence since the late 1990s (Foo, 2008; Lester, 2006; Marinho and Norberto Rocha, 2023). However, this presence increased during the public health crisis, especially when the institutions were forced to close for in-person visits and any other type of activity (Finnis and Kennedy, 2020). According to reports from the International Council of Museums [ICOM] (2020), 48% of Latin American institutions increased their activity on social media, and almost 40% started to offer or build up the number of online exhibitions and activities. As a global trend, between April 2020 and May 2021, museums allocated more professionals to online activities and improved or were considering improving their initiatives on the internet (International Council of Museums [ICOM], 2021).

This trend, however, brought many challenges. In Brazil, for instance, a survey from the Brazilian coordination of the Committee for Education and Cultural Action of the International Council of Museums (CECA-BR/ICOM) and the Museum Educators Networks in Brazil (REM-BR) collected information about the situation museums experienced in the first months of the COVID-19 pandemic (Almeida et al., 2021). The results showed structural problems in funding and management and the need to train professionals to carry out digital, remote, and online education initiatives. As museums started operating with fewer employees and lower levels of investment, they had to reinvent

themselves to occupy the online environment, often without preparation and training (Finnis and Kennedy, 2020).

In addition, challenges existing in the in-person environment continued in the online context. The accessibility and inclusion of people with disabilities are issues that many museums are still navigating [as shown by Norberto Rocha and Abreu (2024), Zakaria (2023), Ferreira et al. (2023), Fernandes and Norberto Rocha (2022)]. The new context of more intense and broad online actions increased and complexified these accessibility issues and concerns for these institutions (Agostino et al., 2020; King et al., 2021).

This exploratory study aims to map and analyze the accessibility of online exhibitions provided by Brazilian science museums and centers during the COVID-19 pandemic. On the following topics, we target the theme of accessibility in museums in Brazil, discuss online exhibitions and accessibility, and briefly explain some of the accessibility resources in the digital world.

2 Access and inclusion in museums in Brazil

Argyropoulos and Kanari (2019), p.125 explain that “educational policies initiatives toward an inclusive society have become more and more intensive in the last decades” as the right to participate in different sectors of social life, education, and culture is grounded on the social model of disability. Sandell et al. (2010) show that, in recent decades, audiences with disabilities have increasingly become a more important topic of discussion in museums and in various publications, seminars, conferences, and manuals. Moussouri (2007) highlights that the social model has influenced the change and adaptation of disability-related research and practice in museum and science communication studies. Thus, institutions have become increasingly concerned with inclusion, which has been reflected in their practice.

In the specific context of science museums and centers, there is a growing effort to map institutions and document accessible practices, as was shown in the development of the *Guide to Science Centers and Museums of Latin America and the Caribbean* (Massarani et al., 2015, 2023) by the Network for the Popularization of Science and Technology in Latin America and the Caribbean, known as RedPOP. As an improvement notice through its three editions (2009, 2015, 2023), the latest version added a few characteristics about accessibility to the institutions’ descriptions (Vicente et al., 2024).

Recognizing the importance of addressing accessible museum practices more specifically, the *Guide* provided an overview of 110 institutions, 69 of which are Brazilian, that voluntarily responded to a survey on their accessibility status – especially regarding physical, attitudinal, and communicational types of accessibility. The survey revealed that, although most of these museums have physical accessibility resources, they still lack attitudinal and communicational strategies to promote the accessibility and inclusion of people with disabilities (Norberto Rocha et al., 2020). The research, however, focused on self-declaration and the point of view of the institutions, not bringing a deeper understanding of specific museums' realities and museums' different audiences with disabilities.

To fill that gap, Brazilian researchers are implementing exploratory and qualitative research in science museums with people with disabilities. Some qualitative studies reinforce the research results. Fernandes and Norberto Rocha (2022), for instance, investigated the experience of two groups of adults with visual disabilities in two science museums in Rio de Janeiro (Brazil). The analysis of the data collected by recording their visits through a subjective camera shows that: (a) physical accessibility, related to the internal architectural aspects, was well-developed, although other elements need improvement; (b) attitudinal accessibility was present because of the guidance and work of the museums' educators; (c) communicational accessibility was rare in the museums, either due to a lack of diversified equipment, media or resources for both internal and external communication. Also, using the same recording method, Pita-Carmo and Massarani (2022) studied nine young deaf people—sign language users—who visited three science centers in Rio de Janeiro, Brazil. The results showed that they faced several challenges, mainly on the communicational and attitudinal dimensions, which arose from the lack of training and confidence of the museums' staff to welcome the museums' audience and organize activities addressing their specific ways of interacting with the contents displayed and from the lack of sign language on the exhibitions and other visual resources that could facilitate communication. In addition to addressing accessibility for deaf individuals, Heck (2024) also examined accessibility for blind individuals at a museum in Porto Alegre (Brazil), highlighting the importance of sensory and auditory resources, such as audio description and Braille, but especially the welcoming attitude and willingness to assist with activities. Finally, Silva (2022) showed that the most significant barriers for people with Down Syndrome engaging with the exhibition of the Museum of Tomorrow (Rio de Janeiro, Brazil) were the massive amount of information, visual and audio elements in the exhibition gallery and the complexity of its communication in written language and philosophical and abstract ideas.

Challenges like these exist in the on-the-ground actions of science museums and expand to their online activities, a research topic included in Brazilian researchers' efforts. Norberto Rocha et al. (2017) analyzed investigations indexed on the *PublicAcessibilidade*, a curated database on museum and cultural accessibility. After analyzing 54 Brazilian articles in 153 journals published between 2006 and 2016, the authors pointed out the prevalence of discussions about educational and mediation programs and specific strategies regarding visitors with visual disabilities. Only one out of 54 discussed assistive technologies in the online museum context. Also, in line with this, Leandro

et al. (2021) reviewed 12 Brazilians' Masters and Ph.D. dissertations focused on science museums' and centers' accessibility, most of which included people with visual or hearing disabilities as a specific group focus, and one which included an accessibility analysis of the websites of three museums.

Our research group has invested in studying accessibility in online exhibitions through the development of web accessibility indicators specific to online museums and exhibitions and their application to analyzing exhibitions (for example, Andrade, 2022; Carvalho de Mattos Marinho and Norberto Rocha, 2022; Marinho, 2023). Marinho and Norberto Rocha (2024) analyzed Brazilian and international articles through a systematized review, finding that most pieces address the topic through a technical perspective, with fewer examples of visitor experience research or methodologies that involve the direct participation of people with disabilities. Despite the ongoing efforts to build and maintain a museum presence in the web environment, we still encounter investigation gaps in web accessibility and inclusion in Brazil. Thus, the present study aims to map and analyze the accessibility of online exhibitions provided by Brazilian science museums and centers in 2020.

3 Online exhibitions and accessibility

The application of computer technology in museums dates to the 1960s and the integration of museum activity with the World Wide Web. The 1990s marked the beginning of the development of the internet, which continues to this day (Schweibenz, 2019). Foo (2008) highlights that an online exhibition, depending on the format, can allow, in the same space, interaction with different types of media, navigation through modules and links according to the visitor's choice, and a personalization of the experience, promoting understanding and learning in ways different from those experienced in physical exhibitions.

Different media types are used to organize an online exhibition: texts, images, videos, 360° panoramic photographs, immersive environments, games, interactive plugins, and virtual meetings. Often, only one media type is chosen; other times, they are combined. Some online exhibitions arise from digitizing or rendering collections, objects, and environments that exist in person. In contrast, others are structured for the independent exhibition of a physical space; in a website structure, these are the most popular and most recently employed models (Urbaneja, 2019).

Online exhibitions structured by digitizing or rendering a physical space are those whose media and information are arranged in a three-dimensional view replicating a physical space and are connected non-linearly—in hypermedia. In them, unique web features are integrated into 3D images, generating an immersive tool from the multisensory stimuli the visitors perceive (Sylaiou et al., 2010). What started with simple graphics has developed into advanced scanning and 3D modeling technologies that have improved over the years.

Another format is that online exhibitions are not tied to physical spaces. The opportunity to explore a digital medium and its unique characteristics, independent of visualizing a physical environment, arises from advancements in network technologies. Just as arrangement in three-dimensional space is part of an exhibition's information, the structure of an exhibition in hypermedia is integral to the content itself, serving as a vehicle for the

visitor's creativity (Kraemer, 2014), and is essential for shaping the experience. This model is still underexplored by museums in Latin America and the Caribbean. In 2020, a UNESCO report that examined 800 virtual activities in museums worldwide revealed that about 90% of those promoted in the region are based on existing resources from physical museums that have been digitized (UNESCO, 2020).

Online exhibitions and other web-based museum activities are as diverse as in-person museum formats and can be hosted on various platforms. Platforms for creating and managing websites and social networks have specific requirements regarding programming languages and internal tools for structuring content. This impacts how media content is displayed, the possibilities for user interaction, and the implementation of accessibility features. For example, Facebook, Twitter, and Instagram include tools for embedding the alt attribute (Abreu and Norberto Rocha, 2021). Facebook has an alt text component, typically used for brief image descriptions, integrated into its structure and allows subtitles to be added to videos posted on the platform via SubRip (.srt) files. Instagram also offers assistive features, including embedded alt text for images and automatic captioning for videos in the feed. It indicates that its platform is accessible to screen readers and alternative navigation methods (Instagram, n.d.). Regarding YouTube, creating or uploading subtitle files for videos hosted on the platform is an option. This allows viewers to customize their presentation through font color, size, and placement on the video screen. The platform is also compatible with the desktop system's assistive resources and navigation via screen readers (YouTube, n.d.).

Accessibility can be enhanced for websites, particularly those developed using authoring tools, since these sites are created directly through programming languages and permit the incorporation of various resources into their code. The choice of authoring tools significantly impacts web accessibility: tools with limited accessibility features may necessitate that developers manually insert or modify the website code (W3C WAI, 2018). For platforms like Google Sites, the ability to manipulate the website's code is restricted, so users must depend on the assistive resources provided by the platform, such as alt text for uploaded images, link customization, and suitable text size and alignment (Sites Help, n.d.).

As norms and guidelines govern accessibility in the in-person and physical realms of society, the online space also has its own set of standards and best practices—such as the international Web Content Accessibility Guidelines (WCAG). In Brazil, internet accessibility is mandated by law: “Accessibility is mandatory on websites operated by companies with headquarters or commercial presence in the country or by government agencies, to be used by individuals with disabilities, ensuring access to the available information, in accordance with the best accessibility practices and guidelines internationally recognized” (Brasil, 2015). In March 2025, the Brazilian Association of Technical Norms (ABNT) released the web accessibility regulation (ABNT NBR 17225), developed through a collaborative process conducted by the Brazilian Accessibility Committee. Based on WCAG 2.2, the document comprises 146 guidelines and provides technical resources, recommendations, orientations, and checklists for web developers (ABNT, 2025).

Following national and international guidelines can be challenging for websites in general. A survey by BigDataCorp in partnership with the “Web para Todos” movement revealed that only 2.9% of Brazilian websites met all the analyzed accessibility recommendations (MWPT, 2024). Rojas et al. (2020) presented a case of applying the WCAG 2.1 guidelines in developing an online museum. The authors' report emphasized the importance of considering accessibility from the initial stage of structuring online exhibitions. However, the report also highlighted the necessity of including resources to build diverse and skilled teams and to ensure the participation of people with disabilities.

Focusing on our research context, we add that out of the 109 Latin American science museums and centers that responded to a survey, only 79.8% had websites. Furthermore, most of those with websites lacked essential accessibility features, such as contrast options, customizable fonts, sign language offerings, translations into other languages, keyboard navigation, hierarchical content organization, the proper use of hyperlinks, screen reader compatibility, image and figure descriptions, and alternative text (Norberto Rocha et al., 2020; Abreu and Norberto Rocha, 2021). Among the institutions that reported having websites and at least one accessibility feature (32%), the survey indicated that the majority (84%) only included customizable text and translations into languages other than sign languages. Only three of the 109 institutions reported having at least three simultaneous web accessibility resources.

It is significant to note that in any website or online activity, offering more than one online accessibility strategy—especially those that can be used simultaneously—is essential for providing a diverse audience with better opportunities to navigate, access, understand, and interact with the content. In the case of the online exhibition, the types of media used (e.g., text, photos or static digital images, 360° images or moving images, videos, and their combinations) and the platform it is built on directly influence the implementation of accessibility strategies (W3C, 2015).

To better understand which accessibility strategies are considered, we describe a few commonly used ones and explain them in the following section.

3.1 Understanding some online accessibility strategies and assistive resources

Ensuring web accessibility means that different people, including those with disabilities, may participate in barrier-free online activities.

There are several methods for ensuring accessibility on a web page or in an online exhibition. Guided by the Web Content Accessibility Guidelines (WCAG), created by the World Wide Web Consortium (W3C, 2018), as well as relevant literature—such as works by Dubois et al. (2014), Vigo et al. (2013), Flor et al. (2009), Leporini and Norscia (2008), Rojas et al. (2020), Sloan et al. (2006), we can list some of these methods. In this study, they are termed “accessibility strategies” and/or “assistive technology (AT) resources”: alternative texts, screen reader and keyboard compatibility, narration, sign language interpretation or translation software, and customizable text. Although strategies must

be combined and applied with appropriate coding or organization depending on the platform used, they can encompass people with different disabilities and allow them to “perceive, understand, navigate, and interact with the Web” (W3C WAI, 2022).

The alternative text, or alt attribute, was initially created for HTML documents to provide a substitute message when an image or HTML element was not rendered (Abreu and Norberto Rocha, 2021). For screen readers to access the information provided, it must include a simplified and relevant textual description. This concept is applied across various platforms, not necessarily requiring a markup language (HTML). For example, platforms like Google Sites and social networks like Facebook, Twitter, and Instagram have internal tools for the alt attribute (Abreu and Norberto Rocha, 2021). It is relevant to highlight that alternative text and audio description are different. The audio description provides complete and detailed information about the image. In contrast, the alt attribute only provides essential information regarding the context, preferably not exceeding 125 characters. This is a suggested best practice based on screen readers’ inability to navigate forward or backward or pause and resume midway through alt text because many screen readers, e.g., Jaws, tend to split the alt text into different blocks after 125 characters.¹

Screen reader and keyboard navigation compatibility refer to the ability to access and understand a webpage or digital content without relying on a mouse. They are important for users with physical, motor, or visual disabilities, as they allow them to navigate and interact with digital content. Screen readers convert text and visual information on a screen into speech or Braille output, making the content accessible to individuals with disabilities.

Some online exhibitions are hosted on Google platforms, like YouTube and Google Arts and Culture, which provide default keyboard navigation options. Also, many templates on website construction platforms, like WordPress, include keyboard navigation accessibility features by default. It is easy to find these templates by filtering for “accessibility” in the template database search engine, which is crucial for search engine optimization and boosts website traffic. To be accessible via keyboard, a website must have intuitive and predictable operability. For example, the Tab and Shift + Tab commands move forward or backward between control elements, the Space or Enter key activates the currently focused element and the Esc key exits an active user prompt or dialog. Because of this, sequential navigation, design, and implementation errors can lead to an unexpected tab order, make the page less intuitive, and skip certain elements. This can disorient and confuse screen reader users, hindering keyboard users’ ability to navigate effectively (Chiou et al., 2023).

The narration serves, in general, as an audio resource that informs users about the content and details of the exhibitions. This resource enhances the exhibition experience by incorporating new elements into a visit to an online exhibition or website through oral narration. In contrast, audio descriptions interpret visual elements or information. They involve detailing events and images presented in live performances and various media recorded previously. When an image includes an audio description on a website, it can easily

be recognized by mouseover, or, for users of screen readers, the audio description will be read aloud. It can also be identified by its universal symbol (AD).

Sign language interpretation or translation software, usually indicated by a symbol leading to the plugin at one of the corners of the browser, are functions that interpret or translate content into sign languages². Using these, websites can rely on windows with interpreters or plugins to translate texts, images, and videos through virtual avatars on the web page. Captioning and subtitles do not replace the interpretation or translation into sign languages.

Customizable text (W3C, 2018), such as font and contrast changes, is implemented on web pages to allow users to choose the best personal settings to read the content. It enables access to information for people with visual disabilities, autistic spectrum disorder, and intellectual disabilities, among others. We can identify its existence through an accessibility icon at one of the corners of the browser page.

All these specificities add possibilities and challenges for hosting exhibitions on the web, which is why developing online exhibitions is a complex task. Investigations into the accessibility of museums’ online activities indicate that a multidisciplinary, multi-professional effort is needed to face the challenges presented in the online world (Flor et al., 2009; Leporini and Norscia, 2008; Rojas et al., 2020).

4 Materials and methods

This exploratory study aims to map and analyze the accessibility of online exhibitions provided by Brazilian science museums and centers during the COVID-19 pandemic. The data was collected between June and July 2020, when the Brazilian museums were closed for in-person visits. The authors of this paper, who are not persons with disabilities, collected and analyzed all the data.

The starting point for selecting the museums that would participate in the research was the Brazilian museums listed in the *Guide to Accessible Science Museums and Centers of Latin America and the Caribbean* (Norberto Rocha et al., 2017), which identified 69 science museums and centers that provided at least one type of accessibility strategy in their physical environments. We chose to conduct this study on these institutions because they were already engaged in promoting accessibility in their physical spaces, making it likely that they could also offer accessibility in their online exhibitions. The *Guide* remains the only mapping survey focused on accessible practices in science museums and centers across Latin America and the Caribbean. This unique focus motivated our decision to use it as the source for institutions.

In the initial data collection phase, we aimed to identify which pre-selected science museums and centers offered free online exhibitions. To do this, we searched for posts or announcements on their primary online communication channels: websites, Facebook, and Instagram, using specific keywords. The following search keywords, written in Portuguese, were utilized to map their various online exhibitions: “virtual visit,” “virtual exhibition,”

¹ Source: <https://www.maine.edu/content-management/accessibility/images/alt-text/> and <https://www.w3.org/WAI/GL/WCAG20/tests/test3.html>. Accessed on: 05 Nov. 2024.

² Source: Hand Talk. Available at: <https://www.handtalk.me/br/> (Accessed: 05 November 2024).

“virtual tour,” “online visit,” “online exhibition,” and “online tour.” These terms were chosen because they represent the most common expressions for online exhibitions. The searches frequently yielded communication pieces on the institutions’ websites and social media posts regarding existing online exhibitions, often including the activity title or URL. All mentions were organized in a spreadsheet categorized by institution. Those with inactive URLs at the time and those available only by appointment were excluded from the analysis.

After identifying and mapping the online exhibitions offered by each of the 69 science museums and centers, we started a second phase dedicated to characterizing the exhibitions, which was divided into descriptive and analytical stages. In the descriptive stage, we organized the data according to the following features: (a) the name of the museum offering the online exhibition(s), (b) the museum’s geographical location, (c) the themes of the online exhibitions, (d) the types of media used in the exhibitions, and e) the platform on which they are based. In the analytical stage, we considered the presence of predefined categories of accessibility strategies and AT resources as follows: alternative text for images, audio descriptions for pictures or videos, screen reader compatibility, keyboard compatibility, interpretation in Brazilian sign language or translation software (such as Handtalk, Vlibras, or similar plugins), narration, video captions, and customizable text (including font size and/or contrast adjustments). Each exhibition was analyzed by two researchers (the authors of this study) in a blinded process using the same set of categories, with no communication between them. A third author was consulted to review the findings if any discrepancies arose. This choice of procedure – applied through multiple research projects in social science studies (Rose and Johnson, 2020) – was made to ensure the validity of the process.

To identify the existence of one or more of these accessibility strategies and AT resources, each researcher navigated through each online exhibition using two paired procedures. First, we searched for the elements using standard browser navigation. Second and complementarily, we applied specialized software—the Web Accessibility Evaluation Tool (WAVE) and the Image Text Alt Viewer—to indicate the provision (or not) of alternative text, audio description, keyboard navigation features (and menu hierarchy, which complicates keyboard and screen reader navigation) and low-contrast errors.

5 Results

In the first phase of data collection, we identified 110 online exhibitions. Out of these, nine were excluded from the analysis: seven because they were announced on the institution’s website but were unavailable during the analysis stage, and two because they required advance bookings for visits. In the second phase, of the remaining 101 valid online exhibitions, we found 94 that provided at least one accessibility strategy or assistive technology resource (Supplementary Table). These 94 online exhibitions were associated with 25 science museums and centers (Table 1).

5.1 Geographical location

As we can see in Table 1, the 25 museums where we identified the availability of online exhibitions featuring at least one accessibility resource are located in four Brazilian regions, excluding the Midwest region. The Southeast region accounts for the majority of the listed online exhibitions with assistive technology resources, with 17 museums providing 70 online exhibitions that include some form of AT resources. The distribution among the states from this region was as follows: Rio de Janeiro (RJ) had eight museums and 49 exhibitions; São Paulo (SP) had six museums and seven exhibitions; Minas Gerais (MG) had three museums and 13 exhibitions. The remaining regions had eight museums offering only 25 online exhibitions: the Northeast region had three museums with 13 online exhibitions; the North region had two museums and nine exhibitions; the South region had three museums with three exhibitions. The four museums boasting the highest number of accessible online exhibitions are: Museu do Amanhã (RJ), Museu Nacional (RJ), Museu de Astronomia e Ciências Afins (MAST/RJ), and DICA (MG).

5.2 Exhibition themes

It was relevant to map the themes covered by the online exhibitions to see if there was a diversity of different social and personal interests represented. The online exhibitions covered the following themes: archaeology, astronomy, earth sciences, life sciences, hard sciences, humanities, paleontology, health sciences, and technology.

Most of the exhibitions analyzed focused on the life sciences field (particularly on biology and chemistry): 37 online exhibitions with AT resources in 17 museums. Museu do Amanhã stands out with eight exhibitions, such as *A época dos humanos*; *A espécie mais perigosa do planeta*; *A vida em suspense*; *Escravos do consumo*; *Planeta em metamorfose*; *Reciclagem e soluções*; *Rios em extinção*; *Superconsumo e desperdício*. Humanities was the theme with the second highest number of exhibitions, featuring 22 online exhibitions across seven museums. Notable among these was the MAST, which showcased five exhibitions analyzed in this theme: *Faz Tempo*, *Leonardo da Vinci: maravilhas mecânicas*, *O Cientista Santos-Dumont*, *Observações do Recife Holandês*, and *Restauração do Pavilhão do Círculo Meridiano Gautier*. Additionally, the Museu do Amanhã presented six exhibitions: *Humanos do porto*, *O porto e seus morros*, *O porto histórico*, *Porto, cultura e arte*, *Praça Mauá*, and *Tour virtual de “Pratodomundo – Comida para 10 bilhões.”*

Regarding the less frequent themes, archaeology was the subject of nine online exhibitions, four belonging to the Museu do Homem Americano – Documentação Arqueológica – Rio São Francisco, *Visita Virtual – Sítios*, *Visita virtual | Épuras*, *Visita virtual | Vestígios*. Paleontology was the subject of seven exhibitions by two museums, five of them put on by the Museu Nacional/UFRJ – Arqueologia Brasileira, Arqueologia pré-colombiana, Brasil indígena, Culturas do Mediterrâneo, Paleontologia. Astronomy was the subject of six exhibitions by three museums, and four of them were put on by MAST – *Exposição Céu Ticuna*, *O Céu que nos Conecta*, *Olhar o Céu*, *Medir a Terra*, *Os Céus dos Povos Originários*. Health Sciences

TABLE 1 Online exhibitions with accessibility strategies and assistive technology (AT) resources by institution and their geographical locations (N = 94).

N	Science museums and centers		Region	State	Online exhibitions with accessibility strategies and AT resources
1	Bosque da Ciência/INPA		North	AM	7
2	Museu Paraense Emílio Goeldi			PA	2
3	Museu Palácio Joaquim Nabuco		Northeast	PE	2
4	Museu do Homem Americano			PI	5
5	Museu Câmara Cascudo (MCC/UFRN)			RN	6
6	Espaço do Conhecimento UFMG		Southeast	MG	2
7	Museu de Ciências Naturais PUC Minas			MG	1
8	Museu Diversão com Ciência e Arte (DICA)			MG	10
9	Museu Nacional/UFRJ			RJ	11
10	Museu de Astronomia e Ciências Afins (MAST)			RJ	14
11	Museu do Amanhã			RJ	18
12	Casa da Ciência – Centro Cultural da Ciência e Tecnologia da UFRJ			RJ	1
13	Espaço Memorial Carlos Chagas Filho			RJ	1
14	Fundação Planetário da Cidade do Rio de Janeiro			RJ	1
15	Museu Aeroespacial (MUSAL)			RJ	1
16	Museu da Vida Fiocruz			RJ	2
17	Aquário de Ubatuba			SP	1
18	Centro de Ciência de Araraquara			SP	1
19	Museu de Microbiologia/Instituto Butantan			SP	1
20	Museu de Saúde Pública Emílio Ribas/Instituto Butantan			SP	1
21	Museu de Zoologia da USP (MZUSP)			SP	2
22	Parque Cientec			SP	1
23	Estação Ciências – Parque Tecnológico Itaipu		South	PR	1
24	Museu Dinâmico Interdisciplinar (MUDI)			PR	1
25	Museu Zoobotânico Augusto Ruschi (MUZAR)			RS	1
	Total	25 museums	4 regions	10 states	94 exhibitions

Source: Authors (2025). The four museums with the highest number of exhibitions with accessibility strategies and assistive technology (AT) resources are highlighted in bold text.

was the subject of five exhibitions in four museums, Alzheimers (Casa da Ciência), Aedes: que mosquito é esse? and Expo Zika: Vidas que Afetam (Museu da Vida Fiocruz), Traços da Saúde em Tempos de Epidemias (Museu de Saúde Pública Emílio Ribas - Instituto Butantan), Coronaceno (Museu do Amanhã). Technology was the subject of five exhibitions put on by four museums, Faça um tour virtual na sala Santos Dumont (MUSAL), 3D Imprimindo o Futuro (MAST), Realidade virtual (DICA), Inovações – Creations Brazilian Style (Museu do Amanhã), Inovações - Criações à Brasileira (Museu do Amanhã). Two exhibitions in two museums were on the hard sciences, Um Olhar nos Espaços de Dimensão (MAST), A beleza escondida da matemática (Museu do Amanhã). Finally, there was only one exhibition museum on earth sciences: Geologia at the Museu Nacional.

5.3 Types of media

Exhibitions presented their content using different and mixed media, directly impacting the demand for different accessibility strategies or AT resources (see Table 2).

Three exhibitions explored diverse media, combining images, videos and 360° images (such as A Câmera é nossa arma

TABLE 2 Predominant media type (N = 94).

Predominant media type	N
Images only	4
Images and text	41
Images, videos and 360° images	3
Images, videos and text	15
360° images only	8
Videos only	23

Source: Authors (2025).

from the Museu Paraense Emílio Goeldi). Four exhibitions relied only on images (for instance, Toxinas da Natureza at MUZAR); eight used 360° images (e.g., Aedes: que mosquito é esse? at the Museu da Vida Fiocruz); 15 explored images, text and videos (e.g., Icnologia, a vida passou por aqui at the Museu Câmara Cascudo); 23 relied on videos (e.g., Visita Virtual Bosque da Ciência “Um dia no Parque” at Bosque da Ciência (BC/INPA). Those combining images and text totaled 41, the most expressive media employed on the exhibitions analyzed (such as A Espécie mais perigosa do planeta at the Museu do Amanhã).

TABLE 3 Accessibility strategies and assistive technology (AT) resources in online exhibitions.

Assistive resources and accessibility strategies	Online exhibitions
Sign language translation software (in Libras)	1
Alternative text	3
Audio description	5
Sign language interpretation (in Libras)	6
Customizable text	6
Captions (in Portuguese)	13
Narration	29
Screen reader compatibility	62
Keyboard compatibility	87

Source: Authors (2025).

The online exhibitions were available on various platforms: 75 were hosted on websites, 14 on YouTube, three on Facebook, and two on Instagram. There was also diversity among those hosted on websites: of the 75, 26 were at Google Arts and Culture, 34 were on institutional websites or hotspots, and others were hosted on platforms such as Google Sites and others specifically for 360° image visualization, like VILA 360 and Era Virtual. As mentioned, the chosen platform influences the overall communication strategy of the exhibition or activity and the potential for applying accessibility guidelines.

5.4 Accessibility strategies and assistive resources

Of the 94 accessible online exhibitions, the majority (87) included at least the keyboard compatibility resource. We anticipated high compliance with this standard because the resource utilizes HTML code from websites and other platforms for navigation, as it is the standard markup language used for structuring websites (W3 Schools, n.d.).

Also, many online exhibitions provided screen reader compatibility: 62 exhibitions were considered compatible after testing with the NVDA software. As with keyboard navigation, screen reader software accesses markup languages to interpret digital resources' structure and provide text-to-speech conversion for the user (Hayley, 2024). HTML allows the developer to structure web pages and other digital applications, providing essential information, such as defined headings and content hierarchies, which can help the user better understand the information displayed.

Regarding the other accessibility strategies and AT resources (Table 3), we identified 29 exhibitions that provided narration (in Portuguese oral language), 13 that included captioning (in Portuguese), six that offered customizable text, six that featured sign language interpretation (in Brazilian Sign Language—Libras), five that provided audio description resources, three that had alternative text for images (two of the five exhibitions had both resources), and one that offered Brazilian sign language translation software.

We recognize that combined accessibility strategies and assistive technology resources are essential for enhancing accessibility and options for various types of users. Therefore, we identified 29 exhibitions that offered three or more assistive resources. Among

these, 12 had three resources, 16 had four resources, and one had seven resources.

6 Discussion

Out of the 101 online exhibitions from Brazilian science museums or centers, 94 presented at least one accessibility strategy or assistive technology resource. The area of knowledge mostly addressed by these exhibitions was the life sciences, mainly biology and chemistry. However, we also noticed various other subject areas, including the humanities, archeology, paleontology, astronomy, health sciences, technology, and earth sciences. Another notable characteristic is that the exhibitions came from 25 different science museums or centers, primarily located in the Southeast region of Brazil, which has the largest number of museums in the country (Norberto Rocha, 2018; Massarani et al., 2015, 2023). Consequently, the four museums with the highest number of accessible online exhibitions – the Museu do Amanhã, the Museu Nacional, MAST, and DICA – are also situated in this region.

The 94 identified online exhibitions present content through various media types, each requiring different assistive resources and accessibility options. By analyzing the data regarding media type and accessibility strategies, we can highlight key findings. Firstly, some exhibitions rely heavily on text. Of the 56 identified, only two provided options for contrast and font size adjustment, and only one offered translation software for Brazilian sign language. These issues can create significant barriers for various audiences, including: a) individuals who rely on customizable text, such as those with visual disabilities, and b) deaf people who use sign language (as these individuals generally have low literacy in Portuguese and may face difficulties in comprehending lengthy written texts).

Secondly, some exhibitions feature static images, consisting solely of photos or a mix of images and other media. Out of 66 exhibitions, only three included alternative text, and two provided audio descriptions, which are essential strategies for people with visual disabilities. One of these three exhibitions combined both resources and offered translation software for Brazilian sign language.

Thirdly, those exhibitions that presented mixed media using static images, 360° images, and videos associated with a narration need strategies to make the content accessible for audiences who cannot see the images (e.g., audio description associated with narration) and for audiences who cannot hear the narration (e.g., captioning and sign language interpretation). In the case of videos and 360° images—used by 44 exhibitions in total—29 provided narration. Less than half of these narrated exhibitions (12) included Portuguese captions. Only two of them featured audio descriptions, which are essential for accessibility for individuals with visual disabilities. Only four exhibitions offered Brazilian sign language interpretation for the narration, and only one exhibition included both sign language interpretation and Portuguese captions. The absence of these assistive technologies creates barriers for the deaf community and sign language users.

As a result, we can observe the limited availability of audio-described and Brazilian sign language content, with only five and six exhibitions offering these options, respectively. This situation is particularly alarming because it directly affects the access of deaf

individuals, sign language users, and those with visual impairments. In a nation where approximately 7 million citizens have visual disabilities and 2.3 million individuals are deaf or hard of hearing, including over 150 thousand who utilize Brazilian sign language (IBGE, 2019), the fact that fewer than 10% of the exhibitions (11 in total) incorporate either of these accessibility strategies highlights a significant lack of accessibility that may exacerbate the exclusion of these individuals.

This study revealed that many exhibitions (87) are compatible with keyboard navigation, as some online exhibitions are hosted on YouTube and Google Arts and Culture or on websites built by platforms offering default keyboard navigation options. Having a greater number of online exhibits that provide this accessibility feature was anticipated. In contrast, other accessibility features, such as virtual sign language interpreters, pose additional implementation challenges, since they require the installation of plugins and/or the use of external services. However, it is critical to note that the options available within this specific strategy were limited, and some displayed keyboard navigation failures (as reported by Chiou et al., 2023). For instance, the navigation order is crucial when interacting with an online exhibition using the keyboard. Nevertheless, design and implementation mistakes lead to unintuitive navigation sequences and context changes, which hinder the ability to explore the exhibition effectively and create additional challenges for users.

Offering various media along with accessibility strategies and assistive technologies in an online exhibition can potentially reach a wider range of people with disabilities and those with different needs. However, utilizing a varied selection of media makes creating an accessible online exhibition more complex. The findings indicate that this presents a challenge for museums, but it does not render accessibility impossible.

An example of an exhibition with mixed media and offering accessibility strategies and assistive technology resources is Zika: Vidas que Afetam (Zika: Affecting Lives) from Museu da Vida Fiocruz. Focusing on public health and showcasing images and stories of lives impacted by Zika, it was launched in 2021 and designed for the online context. Based on a website, the exhibition presented the highest number of assistive resources (seven) in our data analysis, comprising photos, videos, and texts. It includes translation software for Brazilian sign language and customizable text, narrated videos with Portuguese captions and Brazilian sign language interpretation. Additionally, another version of the exhibition offers audio-described images and videos along with a structure that enhances the experience for screen reader users. The study by Marinho (2023) involving blind and low-vision adults attending this exhibition indicates that, despite some barriers, it provides an inclusive experience for this group.

6.1 Practical recommendations for practitioners and researchers

Amid a challenging scenario and certain effective practices in Brazilian museums' online exhibitions, we emphasize that institutions must regard web accessibility as equally crucial as the accessibility of physical spaces. Inclusive online environments can

enhance relationships with visitors with disabilities and potential visitors from other locations, while also expanding the reach of science education and communication. We highlight three actions that can help improve the accessibility of online exhibitions:

1. Incorporate accessibility into online exhibitions and other activities as part of the institutional policy. It is crucial to set specific goals, establish a timeline, and define a budget to create meaningful experiences that will assist the museum in reaching new audiences.
2. Make accessibility a fundamental component in all processes. Planning an online exhibition should consider web accessibility guidelines and indicators (e.g., WCAG 2.2, ABNT, 2025; Carvalho de Mattos Marinho and Norberto Rocha, 2022), along with the involvement of specialized web developers, to ensure that the overall structure, content, and assistive resources are integrated smoothly.
3. Center the motto "nothing about us without us." In addition to applying accessibility strategies and assistive technology resources in an online exhibition to ensure quality, barrier-free visits, professionals and visitors with disabilities should be involved as curators, developers, consultants, and collaborators in visitor experience investigations. We consider this a key recommendation that demonstrates institutional commitment to web accessibility and inclusion.

Investigating the visitor experience is a pathway for developing online exhibitions and accurately assessing their accessibility. Other studies highlight that this viewpoint is underexplored in the field (Marinho and Norberto Rocha, 2024) and that human evaluation and the involvement of people with disabilities are crucial for achieving successful accessibility (Rojas et al., 2020; Silva and Lopes, 2020). Therefore, some approaches in designing the research methodology can guide investigations toward participatory practices and thorough observations:

1. Combine automated and human evaluations of accessibility features in the online exhibition. Automated tools are useful but have limitations, so additional and more thoughtful analysis is necessary, as we applied in the present study.
2. Collaborate with accessibility consultants who are people with disabilities. Their expertise and lived experiences will enhance the analysis and assess whether specific groups can access the online exhibition based on the existing barriers identified.
3. Finally, explore visitor experiences "of" and "with" people with disabilities. The online visitation experience is rarely examined in the field, particularly regarding visitors with disabilities. Inviting different groups to participate in the investigation can yield valuable insights into the relationship between the exhibition's context, structure, and assistive resources. Furthermore, the qualitative analysis component enhances the interpretation of web accessibility, which is often related to more technical aspects.

7 Contributions and limitations

This study is valuable for catalyzing a discussion on the urgent need to invest in accessibility in online exhibitions offered by Brazilian museums. Although we could identify accessible online exhibitions on different themes and areas of knowledge and a few good practices toward inclusion, there are still paths to be developed. There is a demand to increase accessibility in online exhibitions and the number of museums offering them.

The study had broad and ambitious targets: to map online exhibitions from science museums and centers and their accessibility strategies during the COVID-19 pandemic crisis in 2020. We acknowledge that mapping all existing online exhibitions is impossible, as no comprehensive document detailing these initiatives is available. To locate these online exhibitions, we limited our survey to a specific group of institutions that already offer accessible in-person practices, as noted by [Norberto Rocha et al. \(2017\)](#). Therefore, we believe we could expand this study in future research to include additional exhibitions from national and international museums.

An important point to consider is that our study focuses on providing accessibility strategies and assistive technology resources in online exhibitions, which can enhance the participation of people with disabilities in science communication, non-formal education and culture. However, we must recognize that providing these resources does not guarantee inclusion or equitable education. To assess how individuals with disabilities engage with online museum exhibits, how they utilize the available assistive resources, and whether they feel included, the direct participation of people with disabilities is required. This would necessitate more targeted studies that focus on specific audiences and analyze qualitative data in depth [such as [Marinho \(2023\)](#)]. Another point for reflection is our belief that accessibility and its provision are closely tied to the institutional policies of museums. To this end, it is essential to study the context in which the exhibitions were created to understand which factors determine whether or not such resources are made available.

The study collected data during the COVID-19 pandemic, but we could not identify precisely when the exhibitions were created. Indeed, some of them already existed before the pandemic, and further components of them were developed to address the geographical and sanitary barriers imposed by the public health crisis. The lack of this precise information does not change the fact that there is a gap in accessibility in these exhibitions, which impacts the opportunity for non-formal education access by children and adults with disabilities.

Finally, we propose that accessibility and inclusion should be integral to the agenda from the outset and throughout the planning and execution of new online exhibitions. We recognize that this task is challenging, as it requires a multidisciplinary and multi-professional effort. Nonetheless, having varied assistive resources that offer a multimodal experience with choices is essential for reaching diverse audiences and fostering more equitable education, especially for individuals with disabilities. In line with this,

new studies are incorporated into our plans, particularly to evaluate visitors' experiences in online exhibitions and enhance the understanding of non-formal education and science communication in online environments.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JNR: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review and editing. LM: Data curation, Formal Analysis, Investigation, Validation, Visualization, Writing – original draft, Project administration. GH: Formal Analysis, Investigation, Validation, Writing – review and editing. MPdSC: Formal Analysis, Investigation, Validation, Writing – review and editing. WVdA: Formal Analysis, Investigation, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2025.1542430/full#supplementary-material>

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