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Inspecting the Accessibility of Chatbots and Mobile Banking for Emergent Users in the Context of People with Low Literacy

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Abstract: Digital banking services are embedded in people's daily lives. Despite this, these services are not accessible to everyone for various reasons, especially for people with low literacy. The objective of this work was to develop a method of accessibility inspection in mobile banking and banking chatbots, and the examination was directed toward the public mentioned before. For this reason, two inspection sequences were carried out on five Brazilian banking applications, mediated by accessibility considerations based on literature and case studies applied in the contexts of a riverside community and around elderly people with less experience in digital technology, as well as the mapping of design considerations with the Brazilian technical standard aimed at mobile applications and the investigation of banking chatbots made available by these applications. The results found in the inspections indicate how much the design considerations are satisfied, not satisfied and partially satisfied in the inspected applications and the comparison of the two inspections carried out. Additionally, it was possible to review and evaluate design considerations and propose improvements aimed at professionals who intend to develop accessible mobile bankings, as well as the importance of making banking chatbots.

Keywords: Design and Evaluation Considerations, Accessibility, Mobile Banking, Chatbots, Emergent Users, Low Literacy.

1 Introduction

Digital Information and Communication Technologies are increasingly present in people's daily lives, strengthening access to various services, such as financial services. Smartphone use has grown exponentially in recent years. In 2022, smartphones were evaluated as the most used communication tool for internet access [Ministério das Comunicações, 2022].

The COVID-19 pandemic has significantly changed our communication and social interaction patterns. Individuals have had to adapt their work and social routines to adhere to social distancing guidelines and mitigate the risk of service disruptions. The banking sector has also responded to this shift by implementing measures to ensure financial services' continued viability and functionality.

The Brazilian Central Bank (Bacen) launched the Pix service in 2020 [of Brazil, 2022a], enabling instant bank transfers. The main goal of Pix is to optimize the flow of national bank transfers, such as TED (Electronic Funds Transfer) and DOC (Credit Order Document). These transfers were traditionally made in physical terminals (ATMs) and are now available on smartphones through banking service apps. These services have been gradually replaced since January 2024 [FEBRABAN, 2023].

The research conducted by [Fernandes, 2023] highlights that even with the rapid advancements in technology to optimize services, accessible applications are not commonly developed. Among these users who are on the margins of the use of technologies, we have users with low literacy, inserted in the sphere of emerging users, who are included in the work of [Teran, 2022], defined by the characteristics of age, barrier to access to formal education or commonly found in regions far from urban areas.

According to the work plan proposed by the researchers in 2012, the Grand Challenges for HCI Research in Brazil [Baranauskas *et al*., 2012] aimed to discuss research proposals for the next decade. Among the topics covered, the section on Accessibility and Digital Inclusion emphasized that access to ICTs should not only be aimed at people with physical limitations. It is essential to identify the challenges that exclude other society groups from using technology, understand their difficulties, gather data, and take action to make systems inclusive.

The approach to banking systems, which centers on conventional customer service and interaction methods, is undergoing a significant digital transformation through the incorporation of chatbots. Chatbots simulate audio or text dialog and process this information so that the interaction between the user and machine occurs as accurately as possible, using Generative Artificial Intelligence (AI) resources. This new solution is embraced by financial institutions to enhance their customer support, providing more versatile means of interaction with users [Chat2Desk, 2022].

Given this scenario, to examine issues related to accessibility in instant payment services for individuals with low liter-

acy levels, this study performs a design inspection in mobile banking through the design considerations by [Teran, 2022]. Therefore, the design considerations were further refined, and a subsequent design inspection sequence was executed to validate the enhancements and to ascertain any changes in the mobile banking through updates. Thus, the design considerations were compared with the Brazilian Technical Standard for accessibility in mobile applications. Also, the availability of audio and voice resources in banking chatbots was verified.

For this, five mobile banking were selected, and a persona with a low literacy level was defined and used in the two test sequences. Next, we compared the design and evaluation considerations with the Brazilian Technical Standard (NBR) 17060:2022, which is related to accessibility in mobile application accessibility. Finally, we inspected five banking chatbots as an alternative way of proposing accessible solutions for users who find it easier to perform tasks using audio and voice resources.

This article is an extended version of "Inspecting the Accessibility of Instant Payment Systems" originally published in Proceedings of the XXII Brazilian Symposium on Human Factors in Computing Systems (IHC 2023) [Melo *et al*., 2024]. We explored the design considerations by Teran [2022] in the five most used Brazilian mobile banking to include users with low literacy in digital financial services. This new version includes additional research context and related works, an improved research methodology with new stages encompassing design and evaluation considerations created in the original paper, a comparing of NBR 17060:2022 with design and evaluation considerations, and an investigation of banking chatbots studied. The findings and discussions have also been updated, and the conclusions have been refined.

The following sections of this paper are divided into: background (Section 2); related work (Section 3); research method (Section 4) which details the conduct of three scientific studies that are base this article; inspection of mobile banking using the design considerations (Section 5); inspection of five mobile banking using the design and evaluation considerations (Section 6); the comparison of design and evaluation considerations with NBR 17060:2022 (Section 7); the investigation of five banking chatbots (Section 8); presentation of results (Section 9); discussions (Section 10); threats to validity (Section 10.5) and final remarks (Section 11).

2 Background

In conducting literature research to comprehend the issues faced by users with low literacy, definition of digital literacy, as well as guidelines proposed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) focused on accessibility, a study aimed at Google search engines used by the target audience, the accessibility recommendations proposed by Bacen, and Brazilian Technical Standards (ABNT NBR) on accessibility requirements in mobile applications, as well as a work that explores the technical standard in question, as well as evidence of the use of chatbots by emerging users.

Regarding the challenge of literacy difficulties in the context of the digital world, a concept known as digital literacy is elucidated [UNIFASE, 2023], wherein the potential for study and application of learning to utilize computers and their diverse functionalities such as audio and video, typing, and interactive reading are explored. Furthermore, more engaging pedagogical approaches with interactive instructional sessions are examined. In this process, individuals may not necessarily possess adequate literacy skills. However, the proliferation of technology in recent years has prompted even those without essential reading and writing abilities to utilize electronic devices. The individual, despite the challenges faced in reading and writing, can navigate the device and recognize what they are looking for through images and sounds or by constantly searching with touches on the screen that make access easier.

Among several citations and definitions in the work of [Moreira, 2012], digital literacy aligns with users' utilization of digital resources within the technological context. Literate and illiterate individuals can use digital resources such as computers and smartphones. This engagement may involve text-based interactions, more accessible to literate individuals, or non-verbal communication through images, audio, and video. Hence, digitally literate individuals demonstrate an enhanced ability to comprehend actions within interactive systems facilitated by visual cues presented on screens through touch events and animations.

The Education sector of UNESCO [2018a] published an article titled "Designing Inclusive Digital Solutions and Developing Digital Skills" in 2018, delineating guidelines for developing solutions catering to individuals with limited literacy transitioning into the digital realm. This document collaborated with 14 international projects, in which case studies, developmental propositions, and insights substantiate its publication. Thus, its primary focus is to guide digital solution developers, with a secondary emphasis on formulating public policies to regulate and structure accessibility guidelines for individuals with low literacy, to integrate this target audience into the digital environment increasingly.

The guidelines are divided into five stages: (i) design with all users, focusing on their needs and context; (ii) focus on users' digital skills and competencies; (iii) ensure clarity and relevance of content for low-skilled and low-literate users; (iv) use appropriate media and customize user interfaces for low-skilled and low-literate users; and, finally, (v) provide initial and ongoing training and support designed to capture the challenges faced by low-literate individuals, understand their community and its needs, and, based on this perception of the environment, focus on the target audience to identify the characteristics of the difficulties they face. Creating personas encompassing the diverse cases encountered is considered to reflect on accessible solutions for this audience, and the guidelines refer to the general characteristics of low-skilled and low-literate individuals, divided into five topics: (i) cognitive; (ii) confidence; (iii) social environment in which the user is situated; (iv) gender; and (v) access resources available to the user in their region and location.

Another article by UNESCO [2018b], called "Digital Inclusion for Low skilled and Low literate People", presents studies focused on digital solutions for people with low liter-

acy, in which there are many references linked to formal qualifications. However, these challenges no longer justify excluding this demographic from digital inclusion efforts. The work presented is divided into subcategories of interest, such as health and agriculture. The works presented are categorized into subtopics of interest, such as health and agriculture. Methodologies for requirement gathering and the need for continuous support for these applications are outlined. However, only some studies have addressed financial services.

According to Modesto and Ferreira [2013], a study was conducted using Google search engines among individuals of diverse age groups and with similar educational backgrounds. The objective was to derive recommendations for more accessible Internet searches. A contrast was observed between individuals considered to have low literacy levels and those with high literacy levels. Lower literacy levels encountered more incredible difficulty comprehending search engine results, with their limited mastery of written language and reading skills impeding their search process. When a search necessitates a profound understanding of the query or desired outcomes, such users often fail to locate the expected results.

Among the cases reported, one participant in the study assumed that the search process on a computer resembled an informal conversation, expecting similar search outcomes despite spelling errors and lack of grammatical coherence. Another observation is related to the user's focus during search activities: lacking proficiency in digital literacy, the user's attention is primarily directed towards the keyboard. While typing without looking at the screen, they fail to explore the possibility of using filters to refine their search or to identify suggested spelling corrections, which results in a lengthy search. Another factor is the number of results generated by the search. The low literacy user ignored the answers generated in more than four results. Thus, if a standard search yields more than ten results on a page, users anticipate finding their desired information within the first four results, typically visible on the screen without scrolling. This study was conducted in 2013, and no other analysis was found regarding the impact of search engine resources on people with low literacy. Given this, developers and designers must know the interaction characteristics of this target group to improve the construction of accessible resources in their interactive systems [Modesto and Ferreira, 2013].

The accessibility guidelines provided by Bacen are focused on user experience documentation, where the Central Bank acts as an inducer for the adoption of accessibility solutions, indicating the responsibility of providing accessible services to institutions offering instant payment services. Consequently, financial institutions providing the service establish data on solutions developed for individuals with visual, auditory, physical, or mobility impairments. Notably, the accessibility features induced by Bacen do not encompass emerging users. Consequently, the data partially related to emerging users, in the context of individuals with low literacy, are concentrated on individuals with auditory and visual impairments through audio and voice features, as well as facilitated reading and presentation of information [Central Bank of Brazil, 2024].

The solutions developed for visually impaired people in the inspected mobile applications focus on using the native solutions of smartphone operating systems aimed at screen reading, font size, and contrast. Another aspect observed in some of these applications is avoiding photos, icons, or buttons that may impede screen reader functionality. In another description, the resources developed are not specified or do not inform the development of solutions for this audience. Concerning solutions for individuals with hearing impairments, specific applications assert their non-reliance on auditory cues for interacting with app functionalities or do not indicate the availability of accessibility features.

To enhance accessibility for individuals with disabilities in mobile applications, the Brazilian Accessibility Committee has formulated the Brazilian Standard NBR 17060:2022 [ABNT, 2022]. This standard establishes 54 requirements based on functional performance, using the recommendations of WCAG 2.1 (Web Content Accessibility Guidelines) [World Wide Web Consortium, 2023], UAAG 1.0 (User Agent Accessibility Guidelines) [World Wide Web Consortium, 2002] and eMAG 3. 1 (Electronic Government Accessibility Model) [Brazil, 2014]. These requirements include, for example, the incorporation of textual descriptions within visual elements, aiming to promote digital accessibility in mobile applications [ABNT, 2022].

The work by da Costa Nunes and Monteiro [2024] studied NBR 17060:2022, examining the current legislation and emphasizing the significance of complying with established Brazilian standards alongside recommendations from other consumer protection agencies. To achieve this, they applied the "User Stories" proposed by Jeffries *et al*. [2000] to facilitate compliance with NBR 17060:2022 within the software engineering context. Nevertheless, it is essential to note the importance of full compliance with applicable laws, which in the context of this research is related to compliance with accessibility requirements and recommendations for mobile applications.

3 Related Work

To select related work, we considered those whose contribution is related to developing new proposals and design guidelines that favor accessibility for users with low literacy levels when using various device mobile applications. The scientific bases used in the first article were ACM Digital Library (ACM), IEEE Explorer (IEEE), and Scopus. However, the articles returned in the Scopus and IEEE scientific databases were the same as those in the ACM database, a definitive point to use only the articles returned in this based between 2018 and 2022. In this context, new articles from the Brazilian scientific database SOL SBC were inserted and returned using a search string adapted to facilitate the return of works whose themes are still cited little on the national scene between 2019 and 2023. Furthermore, studies referenced in the work of Teran [2022] of great relevance to the research were selected. The strings used are shown in Table 1:

To help software developers in the construction stage of Instant Payment Systems for emerging users, Teran [2022] carried out two case studies in two cities in the northeast of the state of Pará, to collect different experiences of people with low literacy, first-time users or low-income beginners when

Table 1. Search strings used in the ACM and SOL scientific bases

Scientific bases	Search strings	Period
ACM	(”accessibility” OR ”a11y” OR ”ally” OR ”inclus*”) AND (”financial” OR ”payments” OR ”digital pay*” OR ”transation”) AND (”interface”) AND (”low-literacy” OR ”emergent users”) AND (”writ*” OR ”language” OR ”read*” OR ”litera*”)	2018 until 2022
SOL	(”accessibility” OR inclus*) AND (”financial” OR ”payments” OR ”digital pay*” OR ”transation”)	2019 until 2023

using two banking application proposals. With the data collected, the author developed a set of design considerations to minimize barriers related to the digital accessibility of instant payment systems.

Medhi *et al*. [2011] conducted a study to evaluate and improve the accessibility of user interfaces on mobile devices for people with low literacy levels. To achieve this, the authors used ethnographic studies with 90 individuals with low literacy levels from various countries, including India, South Africa, Kenya, and the Philippines, to examine accessibility experiences across different locations. Based on the collected data, the authors observed that interfaces containing the human operator function online perform better for users with low literacy since they can communicate the necessary information to the operator and then have it transcribed. Additionally, it was found that interfaces with audio resources were well accepted by most users, making it essential to ensure familiarity with the language and vocabulary known to these people.

To contribute to a broader range of different user profiles accessing applications for smartphones, Nery *et al*. [2022] implemented a set of customization guidelines based on the principles of Universal Design (UD) and Participatory Design (PD). These guidelines prioritize diversity in product design without requiring adaptations and encourage collaboration between designers and non-designers in the development process. Therefore, a systematic literature mapping on the requirements of accessible configurations for mobile devices was conducted, followed by selecting diverse groups of individuals with disabilities to provide guidelines that would enable accessibility customization in mobile applications to achieve a UD. To this end, the authors collaborated with 12 participants with different types of disabilities to develop proposals for accessible configuration guidelines based on Android and iOS operating systems.

The exploratory research conducted by Capra and Ferreira [2023] delves into the use of ICTs as a communication tool for caregivers of elderly individuals with low levels of education and their family members. A systematic literature mapping and two interviews were conducted with caregivers and another with close relatives to understand the challenges associated with caregivers' limited education and the implications for daily tasks such as hygiene, feeding, and medication administration. Thus, based on the findings obtained through the interviews, a set of recommendations was proposed for developing systems that facilitate effective communication between caregivers and family members.

Due to the increasing use of digital technologies, driven mainly by COVID-19, it became essential to develop alternative smartphone applications that enable swift and easy comprehension of information across diverse socioeconomic user profiles. To analyze and understand the interaction process with mobile devices among individuals with low literacy levels, Srivastava *et al*. [2021] conducted a systematic literature review of smartphone interface usability for people with a low literacy level. The authors developed a design solution from this project to assist developers and User Experience professionals in developing new applications.

To evaluate digital inclusion interfaces and ensure they include visually impaired, elderly, illiterate, functionally illiterate, and deaf users, Tambascia *et al*. [2008] conducted a study based on the Spencer and Cognitive Walkthrough to introduce the Recoverability Walkthrough (RW) method. Selected evaluators implement this method to assume the role of personas that match the user type specified by the evaluation moderator. The evaluation is conducted collaboratively, with evaluators using predefined questions from the RW method to identify areas for design improvement. However, the study highlights that research targeting illiterate and functionally illiterate users is in the early stages. However, there is a clear need for such studies in this area, particularly within developing nations.

The “Workshop on Usability, Accessibility, and Intelligibility applied to interfaces for illiterate, elderly, and disabled people” [Filgueiras *et al*., 2009], integrated into IHC'2008 at the Brazilian Symposium on Human Factors and Computer Systems, aimed from the presented works, to promote accessibility for digitally excluded people. Therefore, it is evident that low literacy levels significantly influence the use of ICTs by this population. Thus, the discourse engendered discussions among researchers to guide potential research directions so that barriers related to usability, accessibility, and intelligibility enable a focused study approach and underscore the importance of implementing solutions in the HCI and computer systems field.

Lopes *et al*. [2022] conducted an accessibility inspection targeting people with visual impairments across four Brazilian banking applications using the SiDi Mobile Accessibility Guide [SIDI, 2019] for manual inspection and the Accessibility Scanner app with Talkback, the native accessibility assistant for Android, configured for automatic inspection. Following a script with five steps covering standard digital application services such as statement display, Pix key creation, bill payment, inter-account transfers, and Pix service transfers, approximately 653 accessibility violations were identified across the four inspected applications. Therefore, it is pertinent to note that depending on the testing methodologies, guidelines, and smartphone accessibility features, the results may vary and complement each other.

The study by Følstad *et al*. [2018] constitutes a quantitative and qualitative analysis of using services through chatbots to comprehend the reliability, usability, and efficiency levels of the services provided. However, in this paper, the use of chatbots is not specially addressed, and the contextual scope is not national. Nevertheless, the analysis of the collected data encompasses reflections and ideas on how to enhance chatbot services to be accessible and effective in their functionality. One point raised in this study is related to more human communication, which is provided with humor but maintains the severe scope of the service. Another critical and unresolved issue relates to the services provided by the

chatbot, which do not encompass the full range of queries and suggestions that a human service could address. Moreover, some interviewees emphasized the importance of the chatbot service being available 24/7 for simple queries, yet effectively answered at any desired time, without waiting for business hours to complete the task. Finally, five recommendations are proposed for developing tools in this context, addressing the needs expressed by the interviewees.

In the context of chatbot utilization, Aribandi *et al*. [2022] created four bots with distinct personalities and interaction styles, aiming to be utilized and evaluated by individuals with low literacy levels, some of whom had never interacted with a smartphone before the study. Consequently, test administrators gave users general knowledge of the application's functionality. Results revealed that users with no prior smartphone experience could interact with the bot and perform searches accurately, albeit after some incomplete trials without third-party assistance. Across all users who tested the bot versions, it was observed that the bot featuring a female voice for interaction garnered greater acceptance, primarily due to the clarity of responses elicited through user interaction. This study was based on two perspectives by Medhi *et al*. [2011] related to individuals with low literacy. However, the study did not delve into issues related to instant payment systems.

Table 2. Comparison table between related work and the present work.

Study	Objetive
Teran [2022]	Assist software developers in designing Instant Payment Systems for emerging users.
Medhi *et al*. [2011]	Improve mobile device user interface accessibility for individuals with low literacy.
Nery *et al*. [2022]	Enhance accessibility to smartphone applications for a diverse range of user profiles by implementing customization guidelines in Universal Design and Participatory Design principles.
Capra and Ferreira [2023]	Understand challenges faced by caregivers with limited education and propose recommendations for developing effective communication systems between caregivers with limited education and family members.
Srivastava *et al*. [2021]	Analyze and understand the interaction process with mobile devices among individuals with low literacy levels.
Tambascia *et al*. [2008]	Evaluate digital inclusion interfaces for visually impaired, elderly, illiterate, functionally illiterate, and hearing impaired individuals.
Filgueiras *et al*. [2009]	Promote accessibility for digitally excluded individuals.
Lopes *et al*. [2022]	Evaluate the accessibility of mobile banking in Brazil for users who have visual impairments.
Følstad *et al*. [2018]	Analyze the reliability, usability, and efficiency of services provided through chatbots and propose recommendations for the development of tools for chatbots.
Aribandi *et al*. [2022]	Improve chatbot experience for low literacy levels and limited smartphone experience users.
Present Work	Apply and refine design considerations to identify and validate accessibility issues in mobile banking and evaluate the feasibility of implementing banking chatbots on smartphones.

Based on the works presented, this study proposes utilizing a set of design considerations by Teran [2022] to validate and identify accessibility-related issues in mobile baking. However, due to the test results, it was necessary to refine these design considerations. This led to a new series of inspections on these instant payment system applications to validate the improvements made. It will also compare accessibility guidelines and standards for instant payment systems and mobile devices and the feasibility of using banking chatbots. In Table 2, it is possible to analyze the difference between the objectives presented in the related studies and the present work.

4 Methods

This study is applied research, as it used a set of design considerations to inspect the digital accessibility of five mobile banking for users with low literacy. It also compared design considerations with technical documentation provided by standard organizations. Furthermore, it is exploratory research, considering the investigations conducted on the interactive systems. Finally, the study adopts a quantitative approach, as the data were collected and analyzed numerically besides involving a critical analysis of the obtained data with banking chatbots and mobile banking inspections.

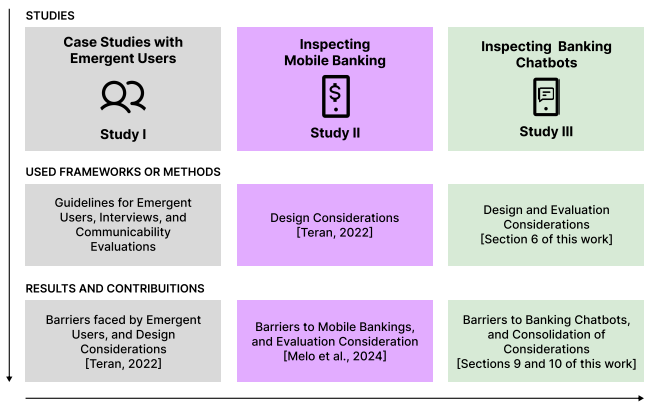

Figure 1. Summary of Scientific Studies

This article was constructed based on three scientific studies (Figure 1). Study I addresses a set of two case studies in which 29 design considerations [Teran, 2022] were generated. Study II highlights the inspection of five mobile banking, which was published in IHC 2023 [Melo *et al*., 2024] and used as the basis for the extension of this article. Study III correlates the contributions provided by Teran [2022] and Melo *et al*. [2024] and, in this sense, presents a set of 33 design and evaluation considerations for the accessibility of emerging users. Furthermore, still in study III, design and evaluation considerations were used to inspect five banking chatbots from the same banking entities as in study II. The following subsections detail the scientific studies that support the construction of this article.

4.1 Study I: Case Studies with Emergent Users

Scientific study 1 was carried out through two case studies with emerging users about accessing financial and digital services. According to Devanuj and Joshi [2013], the emerging users have historically encountered digital access barriers stemming from socio-environmental factors such

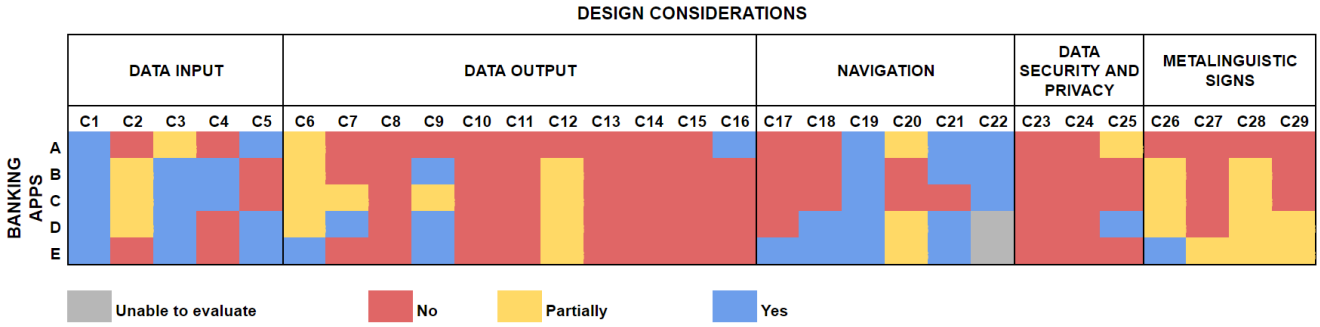

Figure 2. Test results from design considerations Teran [2022] adapted from Melo *et al.* [2024]

as education, longitudinal circumstances, or income. During the study, interviews and two prototype tests were conducted. Furthermore, the Communicability Evaluation Method (CEM) was applied in the two case studies.

As contributions, scientific study 1 presented 29 design considerations (Table 3) for accessibility of emerging users into five dimensions: data input interfaces, data output interfaces, navigation interfaces, interfaces addressing data security and privacy, and interfaces concerning metalinguistic signs (signs that elucidate other signs). The test outcomes for each category are illustrated in Figure 2.

Table 3. Summary of design considerations [Teran, 2022] adapted from Melo *et al.* [2024]

Code	Considerations
C1	Center data types in text entry fields
C2	Use voice commands in system tasks
C3	Activate correct keyboards when interacting with masked fields
C4	Use the keyboard confirmation button to proceed
C5	List the user's keys on the receive screen with Pix
C6	Show illustrations consistent with users' experiences
C7	Show receipts that physically simulate the document
C8	Combine voice alerts with smartphone notifications
C9	Show texts with large fonts and small amounts of characters
C10	Vocally prompt when filling text entry field
C11	Combine voice alert with informed data validator
C12	Provide large, easy-to-understand icons
C13	Include summaries of data reported through voice output
C14	Include voice feature on and off options
C15	Include a graph to visualize future credit or debit
C16	List your favorite recipients on the pay with Pix screen
C17	Break forms into small interaction activities
C18	Include options to change previously entered data
C19	Set clear orders on forms to minimize errors
C20	Present visual and sound effects on system screens
C21	Avoid the back button on screens after completing tasks
C22	Include an option to create a Pix key in the first access information
C23	Combine speech recognition and questions in voice features
C24	Report sensitive data using voice in secure environments
C25	Automatically capture codes sent to your smartphone
C26	Provide a virtual agent to assist users with their tasks
C27	Provide interaction hints when an element is pressed
C28	Show briefing in large font, few characters and highlighted keywords
C29	Combine voice features and animated illustrations in instructions

4.2 Study II: Inspecting Mobile Banking

Scientific study II was conducted through mobile banking inspection. Inspections were based on the design considerations [Teran, 2022] and persona approach, aiming for validations that resonate more closely with the reality of individuals with low literacy. Since the characteristics of emerging users [Devanuj and Joshi, 2013] and the definition of persona based on the expression of diversity [Aquino and Filgueiras, 2008], the following fictitious user was designed:

- **Name:** Maria;
- **Context:** Maria is 30 years old, completed elementary school, and works as a freelancer in the riverside region, located in the metropolitan region of the city of Belém; The place where Maria lives has access to very limited infrastructure and educational resources, which makes it difficult for her to come into contact with and learn about new technologies;
- **Forces:** Maria has been working informally in the city where she lives since she was 16 years old, eliminating the need for specific technology knowledge. Despite her difficulties, Maria is quite resilient in facing challenges in her daily life;
- **Behavior:** prefers visual information and simple instructions with little text;
- **Problem:** with the rise of government-provided financial services and the ease provided by the Pix service, she needs to use mobile banking to receive and make Pix. She is concerned that her limitations in formal education may make it difficult for her to use her smartphone for these activities;
- **Solution:** include tutorials exemplifying the use of the instant payments functionality and offer audio support to help resolve possible doubts or problems in carrying out your operations.

Study II findings (Section 5) are associated with the test validations and their outcomes based on each evaluated mobile banking, contemplating the design considerations Teran [2022] in a prioritization order and evolution through conducted tests. Therefore, insights regarding applying the method employing design considerations within the context of users with low literacy will be abstracted.

In ranking complaints on the Bacen [Central Bank of Brazil, 2023] website, the five mobile banking in the conglomerate of active financial institution partners until the first quarter of 2023 were selected. To anonymize the names of the banks in this work, as the purpose is to evaluate and, with the results found, propose improvements to the design considerations [Teran, 2022], the selected mobile banking's were

named Application A, Application B, Application C, Application D and Application E.

Table 4. Active customers until the 1st quarter of 2023 Central Bank of Brazil [2023] adapted from Melo *et al*. [2024]

Name	Number of customers
Application A	149.855.561
Application B	103.666.074
Application C	99.015.603
Application D	74.150.080
Application E	73.168.970

The accessibility inspection of each mobile banking was carried out on smartphones with Android and iOS operating systems owned by the authors of this work. The order of tests was defined based on the number of active users, in descending order, according to Table 4, as well as the order of application of design considerations followed the ascending order of Table 3.

In study II, two sequences of 145 checks were carried out, where 37 tests had a favorable result, 28 tests had a partial result, 78 tests had a negative result, and two tests in which it was not possible to evaluate when the design consideration [Teran, 2022] was not assessed. The first sequence was carried out more sparingly, exploring the possibilities of bias in interpreting the descriptions of the considerations and repeating the tests when necessary. The second sequence was carried out more quickly, with the effect of refining the data that was collected in the first sequence of tests. All simulated tasks were effectively completed to obtain a concrete result using design considerations. Test data in more detail is available in a remote repository, accessible at Melo [2024].

4.3 Study III: Inspecting Banking Chatbots

Scientific study III was conducted through banking chatbot inspections. For this, was refined and consolidated the considerations generated by Teran [2022] and Melo *et al*. [2024] in a set of 33 design and evaluation considerations (Table 5) for emerging users accessing digital financial services.

New inspections were carried out using the design and evaluation considerations in banking chatbots of the same five financial institution partners evaluated in study II, aiming to investigate if these services are accessible to emerging users. Thus, two sequences of 165 checks were carried out, where 60 tests had a "yes" result, eight tests had a partial result, 95 tests had a "no" result, and two tests had a "cannot evaluate" result, when design and evaluation consideration has not been evaluated.

Due to the need to investigate technical standards applied to mobile applications, the Brazilian Technical Standard NBR 17060:2022 deals with accessibility guidelines for mobile applications based on WCAG 2.1 standards and technical documentation for the most used operating systems (Android and iOS). With this, the design and evaluation considerations were compared with the accessibility recommendations of NBR 17060:2022.

Finally, observing the data obtained in the inspections and the mapping of design and evaluation considerations and technical standards, following the observations of Aribandi *et al*. [2022] and Følstad *et al*. [2018], investigations were carried out into the use of banking chatbots, to consolidate the diverse possibilities in using mobile banking.

5 Inspection of Mobile Banking using Design Considerations

Below, the tests carried out on each mobile banking are described through a quantitative analysis of the results obtained, based on the design considerations [Teran, 2022], which are divided into five dimensions: (i) Input interface data; (ii) Data output interface; (iii) Navigation interface; (iv) Interface related to security and privacy; and (v) Interfaces related to metalinguistic signs.

Among the design considerations evaluated, it was observed that 13.8% had a partial result, which needed to meet all the criteria informed by the consideration proposal, corresponding to DC-3, DC-6, DC-20, and DC-25. Among the design considerations that meet the entire proposal, we have 20.7%. The design considerations are DC-1, DC-5, DC-16, DC-19, DC-21, and DC-22. The majority of 65.5% are the design considerations that are not met by the proposal, corresponding to DC-2, DC-4, DC-7, DC-8, DC-9, DC-10, DC-11, DC-12, DC-13, DC-14, DC-15, DC-17, DC-18, DC-23, DC-24, DC-26, DC-27, DC-28 and DC-29.

Figure 3. Test on Application A adapted from Melo *et al*. [2024]

Figure 3 shows evidence of a test that yielded a yes result related to DC-16: List favorite recipients on the pay with Pix screen. You can see a button on the screen with the text "My Favorites", as proposed by the design above consideration.

Tests on the Application B with the most active customers had 24.15% positive results, with DC-1, DC-3, DC-4, DC-9, DC-19, DC-21 and DC-22. With a partial result, 17.2% was noted, with considerations DC-2, DC-6, DC-12, DC-26 and DC-28. And with 58.65%, the design considerations that were not met DC-5, DC-7, DC-8, DC-10, DC-11, DC-13,

DC-14, DC-15, DC-16, DC-17, DC-18, DC-20, DC-23, DC-24, DC-25, DC-27 and DC-29.

In Figure 4, you can see evidence of DC-2: Use voice commands in system tasks. In the data entry field, next to the search icon, a button with a microphone icon is available, which indicates voice search. This test had partial results, as the application did not recognize the voice commands.

Application C was the third to be tested, and 17.2% had a positive result, considering DC-1, DC-3, DC-4, DC-19 and DC-22. With 24.15%, the design considerations with partial results were DC-2, DC-6, DC-7, DC-9, DC-12, DC-26 and DC-28. And the design considerations that had the negative result DC-5, DC-8, DC-10, DC-11, DC-13, DC-14, DC-15, DC-16, DC-17, DC-18, DC-20, DC-21, DC-23, DC-24, DC-25, DC-27, DC-29.

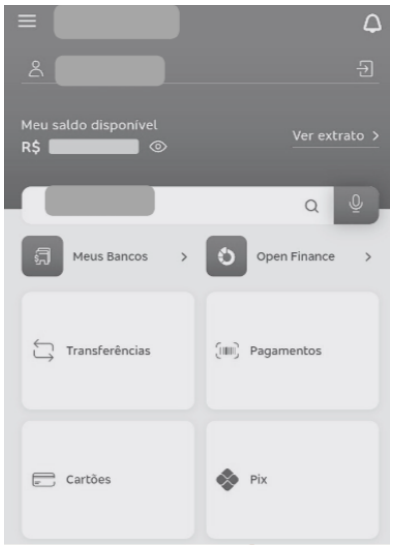

Figure 4. Test on Application B adapted from Melo *et al*. [2024]

Figure 5 highlights two design considerations: DC-9 and DC-26. Which DC-9 corresponds to: Show texts with large fonts and small amounts of characters. The result of this test was partial, given that the font size in the application is small despite containing few characters. And DC-26: Provide a virtual agent to assist users in their tasks, in which a floating button is available in the lower right corner with the text "still have questions?" on the screens. This test had the result.

Application D had a 31.05% positive result for the design considerations, which are DC-1, DC-3, DC-5, DC-7, DC-9, DC-18, DC-19, DC-21 and DC-25. Design considerations with partial result were DC-2, DC-6, DC-12, DC-20, DC-26, DC-28 and DC-29 with 24.15%. Almost half of the tests are equivalent to the negative result, with design considerations DC-4, DC-8, DC-10, DC-11, DC-13, DC-14, DC-15, DC-16, DC-17, DC-23, DC-24, DC-27 corresponding to 41.4%. And with 3.4%, consideration DC-22 had the result "it was not possible to evaluate", as it was impossible to carry out the test. Figure 6 present an example for DC-7: Show receipts that physically simulate the document, which had the result yes only in this application (Application D). A physical receipt contains information about the payer, the recipient, and the transferred amount. It also includes information relating to the transaction, such as its identifier, date, and completion time. The content of a physical receipt usually consists of

Figure 5. Test on Application C adapted from Melo *et al*. [2024]

text only and does not include decorative elements such as icons and images.

Figure 6. Test on Application D adapted from Melo *et al*. [2024]

Application E had 34.5% of design considerations with a positive test result, equivalent to DC-1, DC-3, DC-5, DC-6, DC-9, DC-17, DC-18, DC-19, DC-21 and DC-26. With 17.25%, the partial results design considerations were DC-12, DC-20, DC-27, DC-28 and DC-29. Among the design considerations with a negative result we have DC-2, DC-4, DC-7, DC-8, DC-10, DC-11, DC-13, DC-14, DC-15, DC-16, DC-23, DC-24, DC-25, equivalent to 44.85%. And design consideration DC-22 had the result "could not evaluate" with 3.4%.

Figure 7 present resources where DC-3 and DC-17 were applied. Which DC-3 says: Trigger the correct keyboards when interacting with masked fields. The data entry field asks for a value, and the activated keyboard only shows num-

bers. And DC-17: Divide forms into small interaction activities. Each task is shown separately on the screen when carrying out a transaction with Pix. Both tests had a yes result.

Figure 7. Test on Application E adapted from Melo *et al*. [2024]

6 Inspection of Mobile Banking using Design and Evaluation Considerations

As a base for the two inspection cycles, besides the contributions of Teran and Mota [2024] and Melo *et al*. [2024] (scientific studies I and II), we evolved the design considerations to evaluate the accessibility of mobile baking for emerging users. Thus, we named this framework of design and evaluating considerations. Therefore, due to updates to mobile banking, inspections were carried out again to improve the proposed services and offer new functionalities to users, using design and evaluation considerations.

In Table 5, the 33 design and evaluation considerations are shown, where their dimensions were reorganized to facilitate the flow of tests and how the considerations can be visualized in a mobile banking. This indicates which design and evaluation considerations are related to Visual resource and Audio resources, as well as Data Input and Data Output resources. The effect observed with the reorganization of considerations is consolidated by verifying that a design and evaluation consideration can be in all categories, as indicated in IOVA-33.

The tests carried out with the design considerations and evaluation followed the same script as the test sequence of scientific study II, where each mobile banking was inspected, one at a time, following the ascending order of the table of design and evaluation considerations and the ordering of active clients, as shown in Table 4. Likewise, the test results data were organized and named similarly, with the results "no", "yes", "partially" and "could not evaluate". Data from tests carried out with design and evaluation considerations are shown in Figure 8.

When analyzing the data from the 165 inspections carried out, using design and evaluation considerations, 56.97% had a "no" result, 36.97% had a "yes" result, 4.85% had the result "partially", and 1.21% had the result "it was not possible to evaluate".

Tests on the mobile banking with the most active customers, Application A, had 42.42% of tests with a "yes" result, with design and evaluation considerations IV-1, IV-2, IV-8, IA-9, OV-13 , OV-15, OV-16, OV-18, OV-20, OV-21, OV-23, OV-24, OV-25 and IOV-32. With a "partially" result, 3.03% with design and evaluation considerations IV-3 and with a "no" result, 54.55% with design and evaluation considerations IV-4, IV- 5, IV-6, IV-7, IA-10, IA-11, IA-12, OV-14, OV-17, OV-19, OV-22, OV-26, OA-27, OA-28, OA-29, OA-30, OA-31, IOV-33. In this application (Application A), there were no tests with the result "unable to evaluate".

In Figure 9, it is possible to observe the evidence of the design and evaluation consideration OV-15 that discusses presenting easy-to-understand icons to the user, which are shown on the screen and captioned, as well as the IA-9 that corresponds to activate the voice command using buttons or by pronouncing activation keywords, where the button to perform the search by text and voice was made available through an update, under the title of the Pix screen.

In Application B, tests with a "yes" result were 42.42%, with design and evaluation considerations IV-1, IV-2, IV-4, IV-6, IV-8, IA-9 , OV-15, OV-16, OV-20, OV-21, OV-23, OV-24, OV-25 and IOV-32. With a "partial" result, it was 6.06% with design and evaluation considerations IV-3 and OV-18. And with 51.52% of tests resulting in a "no" result, design and evaluation considerations IV-5, IV-7, IA-10, IA-11, IA-12, OV-13, OV- 14, OV-17, OV-19, OV-22, OV-26, OA-27, OA-28, OA-29, OA-30, OA-31 and IOVA-33. In this mobile banking (Application B), there were no tests with the result "unable to evaluate".

According to security-related updates to the Application B, it was impossible to record any testing evidence, as any recording via screenshot means the mobile banking does not perform the action, blocking the capture of information and showing the screen as black. In this sense, to validate the Application B behavior's, the account of the respective mobile banking was accessed on the desktop, and the behavior was similar without the possibility of capturing the screen.

Application C it worked, about 30.30% of the tests had a "yes" result, with design and evaluation considerations IV-2, IV-5, IV-8, IA-9, OV-13, OV-15, OV-20, OV-22, OV-23 and OV-24. With "partial" results, 9.09% of tests, with design and evaluation considerations IV-1, OV-17, and OV-18. With the result "no", 60.61% were evidenced, with design and evaluation considerations IV-3, IV-4, IV-6, IV-7, IA-10, IA-11, IA- 12, OV-14, OV-16, OV-19, OV-21, OV-25, OV-26, OA-27, OA-28, OA-29, OA-30, OA-31, IOV-32 and IOVA-33. In this application (Application C), there were no tests with results that were "unable to evaluate".

When checking the Application C on two different mobile devices, it was observed that the font size is variable without a standard configuration through the application. As a result, the genuine settings of the mobile devices' operating systems were not changed. In this case, the design and evaluation

Table 5. Design and evaluation considerations adapted from Teran *et al*. [2024]

Interface Categories	Design and evaluation considerations (Study III)	Design Considerations (Study I)	Reorganization proposal (Study II)	Literature base and Case study
Data input and Visual	IV-1. Adapt the mask of a data field according to your input	DC-1	IC-1	CS1 and CS2
	IV-2. Present the keyboard corresponding to the data entry	DC-3	IC-2	Thies
	IV-3. Use the keyboard confirmation button to proceed with a task	DC-4	IC-3	CS2
	IV-4. Provide an on and off button for voice assistant support	DC-14	VC-1	Thies; Srivastava *et al.*; Capra *et al.*; Gupta *et al.*
	IV-5. When performing form-filling tasks, display a single task at a time on the screen	DC-17	IC-12	Thies; Srivastava *et al.* CS1 and CS2
	IV-6. After the first access instructions, provide a button to create a Pix key	DC-22	IC-15	of Brazil / CS1 and CS2
	IV-7. Automatically copy the validation code sent to the smartphone	DC-25	IC-16	Srivastava *et al.* / CS2
	IV-8. As Instructions should be brief and highlight keywords in specific actions	DC-9/28	IC-7	Srivastava *et al.*; Capra *et al.* / CS1 and CS2
Data input and Audio	IA-9. Trigger voice commands via buttons or by pronouncing activation keywords	DC-2	VC-2	Thies / CS2
	IA-10. Provide voice feedback to indicate keyboard button presses by users	DC-10	AC-2	Srivastava *et al.* Capra *et al.* / CS2
	IA-11. Strengthen user authentication via voice command with non-sensitive personal data	DC-23/24	VC-3	Randhawa *et al.* / CS2
	IA-12. Provide voice alerts for downtime	DC-26	VC-4	Srivastava *et al.*; Capra *et al.* / CS2
Data output and Visual	OV-13. Present a list of created Pix keys	DC-5	IC-4	CS1 and CS2
	OV-14. After completing the creation of a Pix key, add a "Receive via Pix" button to the screen	DC-5	IC-5	CS1 and CS2
	OV-15. Present icons that are easy to understand for the user	DC-6	VisC-1	Srivastava *et al.*; Capra *et al.* / CS2 and CS2
	OV-16. Present animated illustrations that are easy for the user to understand	DC-12	VisC-1	CS2
	OV-17. Show receipts that simulate the physical document	DC-7	IC-6	Srivastava *et al.*; Capra *et al.* / CS1 and CS2
	OV-18. Provide titles and captions in large fonts, with few characters and highlighted keywords throughout the application	DC-9/28	IC-7	Srivastava *et al.*; Capra *et al.* / CS1 and CS2
	OV-19. Provide a graph that makes it easier to view your balance when sending or receiving a Pix	DC-15	IC-8	Srivastava *et al.* / CS1 and CS2
	OV-20. Display a list of favorite user Pix keys	DC-16	IC-10	Modesto and Ferreira / CS2
	OV-21. Allow the user to favorite the recipient's Pix key in the process of paying with Pix	DC-16	IC-9	Modesto and Ferreira / CS2
	OV-22. Provide the option to edit the data entered before completing the task	DC-18	IC-13	CS1 and CS2
	OV-23. Set clear orders on forms to minimize errors	DC-19	IC-11	CS1 and CS2
	OV-24. Present visual effects when screen changes occur	DC-20	VisC-2	CS1 and CS2
	OV-25. Avoid back buttons on task completion screens	DC-21	IC-14	CS1 and CS2
	OV-26. The voice assistant must ask if the user is in a safe environment before providing personal information	DC-23/24	VC-3	Randhawa *et al.* / CS2
Data outputs and Audio	OA-27. Customize app notification sound with voice assistant	DC-8	AC-1	Srivastava *et al.*; Capra *et al.* / CS2
	OA-28. Provide voice feedback to indicate alerts or errors about user-reported data	DC-11/13	AC-3	Randhawa *et al.*; Capra *et al.* / CS2
	OA-29. Present audio effects when screen changes occur	DC-20	AC-4	CS1 and CS2
	OA-30. Provide an audio description of data previously entered by users	DC-11/13	AC-3	Randhawa *et al.*; Capra *et al.* / CS2
	OA-31. When pressing an element, trigger the audio description to display its name	DC-27	AC-5	CS2
Data Inputs, Data Outputs, and Visual	IOV-32. Help the user through a virtual agent	DC-26	IC-17	Srivastava *et al.*; Capra *et al.* / CS2
Data Inputs, Data Outputs, Visual and Audio	IOVA-33. Use voice assistants and animations to assist users with their tasks	DC-29	VisC-3	Tulaskar; Capra *et al.* / CS1 and CS2

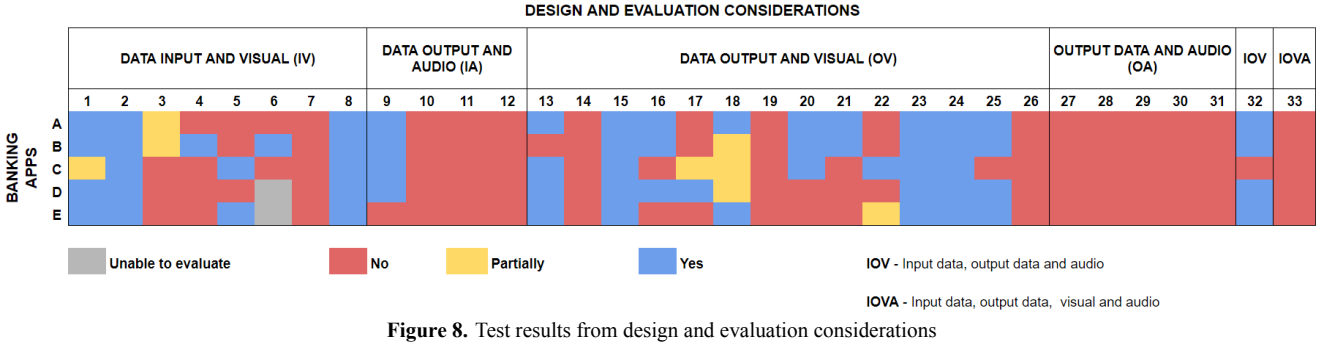

Figure 8. Test results from design and evaluation considerations

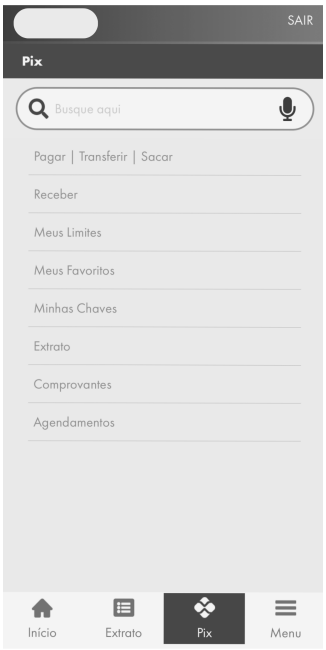

Figure 9. Test on Application A with design and evaluation considerations

consideration evident in Figure 10 corresponds to the OV-18, with a "partial" result, which explains the provision of titles and subtitles with fonts large, with few characters and highlighted keywords.

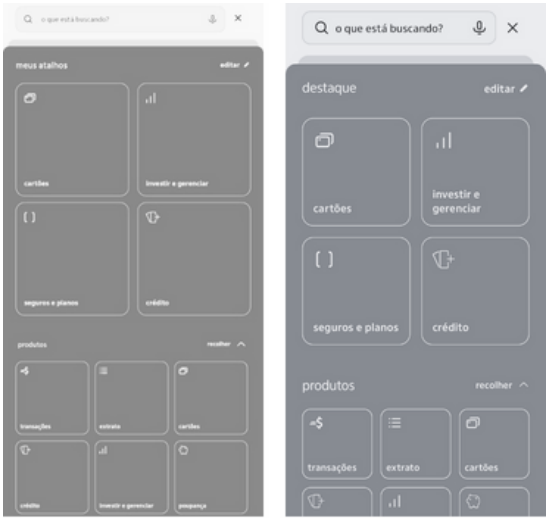

Figure 10. Test on Application C with design and evaluation considerations

In Application D, 36.36% of tests were "yes", with design and evaluation considerations IV-1, IV-2, IV-8, IA-9, OV-13, OV-15, OV-16, OV-17, OV-23, OV-24, OV-25 and IOV-32. With 3.03%, the result "partially" includes the design and evaluation consideration OV-18, more than half of the tests with 57.57% had a "no" result, with design and evaluation considerations IV-3, IV-4, IV-5, IV-7, IA-10, IA-11, IA-12, OV-14, OV-19, OV-20, OV-21, OV-22, OV -26, OA-27, OA-28, OA-29, OA-30, OA-31 and IOVA-33, and 3.03% of the tests with a result "unable to evaluate", with design and evaluation consideration IV-6.

In Figure 11, the design and evaluation consideration IOV-32 is highlighted, which had the result "yes", corresponding to helping the user through a virtual agent.

In the last inspected application, carried out in Application E, tests with a "yes" result scored 33.33%, with design and evaluation considerations IV-1, IV-2, IV-5, IV-8, OV-13, OV- 15, OV-18, OV-23, OV-24, OV-25 and IOV-32. With "partially" result, 3.03% with design and evaluation consideration SV-22. More than half of the tests were evidenced with a "no" result, with 60.61%, covering design and evaluation considerations IV-3, IV-4, IV-7, IA-9, IA-10, IA -11, IA-12, OV-14, OV-16, OV-17, OV-19, OV-20, OV-21, OV-26, OA-27, OA-28, OA-29, OA-30 , OA-31 and IOVA-33. And 3.03% of the tests had the result "unable to evaluate", with design and evaluation consideration IV-6.

Figure 11. Test on Application D with design and evaluation considerations

In Figure 12, it is possible to observe the evidence of design and evaluation consideration with the result "no", indicated by IV-7, corresponding to automatically copying the validation code sent to the smartphone. The application captures the code, so selecting the code to validate it when creating a Pix key is necessary.

7 Comparing of NBR 17060:2022 with Design and Evaluation Considerations

In this section, the requirements and recommendations established by Brazilian Technical Standard 17060:2022 [ABNT, 2022] on accessibility for mobile devices are explored, together with design and evaluation considerations in Table 5 proposed in this work. The comparison of the aspects mentioned is essential to validate the scope of accessibility for mobile applications and their use and compliance with the Brazilian Technical Standard to make mobile banking more accessible.

The design and evaluation considerations are up-to-date, with the related works' analysis, case studies carried out with emerging users, and mobile banking inspections. The Brazilian technical standard was based on accessibility guidelines such as WCAG, eMAG, and accessibility documentation for

Figure 12. Test on Application E with design and evaluation considerations

Android and iOS operating systems, as shown in Figure 13.

Figure 13. Comparison of the Brazilian Technical Standard with design and evaluation considerations

7.1 Brazilian Technical Standard 17060:2022

The Brazilian Standard NBR 17060:2022 was prepared by the Brazilian Accessibility Committee of the Brazilian Association of Technical Standards [ABNT, 2022]. This standard defines accessibility requirements and establishes recommendations for mobile applications, such as smartphones and tablets, based on functional performance. Accessibility requirements and recommendations are divided into four categories: perception and understanding, with 19 requirements and 9 recommendations; control and interaction, with 14 requirements and 5 recommendations; media, with four requirements and three recommendations; and the coding recommendation, to make mobile applications accessible regardless of physical, cognitive and sensory conditions. For the technical standard to be effectively covered, the requirements must be met in the mobile application, and the recommendations must be complementary to propose refinement and accessibility in the user experience.

7.1.1 Perception and Understanding

The first category is perception and understanding, which describes how to avoid the emergence of barriers to understanding the functionalities of mobile applications. In this category, requirements are directed towards the visual standard across the application. As stated in NBR 17060:2022 ABNT [2022], sudden changes in interface design can confuse or mentally exhaust a user when trying to perform a specific action. Figure 14 shows the intersections of design and evaluation considerations with the NBR category of perception and understanding.

Design and evaluation consideration IV-1, which deals with adapting the data field according to your input, is related to requirements 5.1.1.13, which determines form types and fields, and 5.1.1.14, which indicates the instructions for filling in data entry.

Design and evaluation consideration IV-2 presents its description similar to requirement 5.1.1.13, which determines that the input fields correspond to the type of data requested by the system.

The description of design and evaluation consideration IV-5 indicates that the form-filling steps should be divided by screen to prevent users from being misled by multiple tasks on the same screen. The related recommendation is 5.1.1.12 of NBR 17060:2022, which suggests that form fields be presented one per line.

Design and evaluation consideration IV-8, which indicates that instructions should be brief and highlight keywords in specific actions, relates to requirements 5.1.1.14 and recommendations 5.1.1.27 and 5.1.1.28. Together, they present practices to make text fields short and concise, using simple and clear language, making them more accessible and understandable to the user.

Design and evaluation considerations IA-10, OV-24, OA-28, OA-29, and OA-30 indicate providing user feedback via an on-screen event or audio feedback, which relates to requirement 5.1.1.20, which means providing clear feedback to users.

Design and evaluation consideration OV-18 indicates that titles and captions be provided in large fonts, with few characters and highlighted keywords, which relates to requirements 5.1.1.4, 5.1.1.5 and 5.1.1.8 and recommendations 5.1.1.27 and 5.1.1.28, where the descriptions of the requirements above and recommendations, describe in more detail the arrangement of texts in the application, provision of headers and labels to improve user location, clear task descriptions and use in simple and concise language.

Design and evaluation consideration OV-23 description indicate clear orders on forms to mitigate errors. Similarly, requirement 5.1.1.11, in a more comprehensive way, recommends that elements in the interface be distributed in ways widely used to develop interfaces to make the elements shown on the screen more understandable.

Design and evaluation consideration OA-31 and requirement 5.1.1.15 comply, as the descriptions indicate a navigational focus for the user to facilitate visualization of the field description and the user's location in the application 8.

Table 6 shows the sections of the perception and understanding category that were not associated with design and assessment considerations. These sections are intended to address general accessibility issues in mobile applications without addressing the specifics of design and evaluation considerations.

Table 7 shows the design and evaluation considerations that partially relate, with positive or negative impact, to the requirements and recommendations in this category.

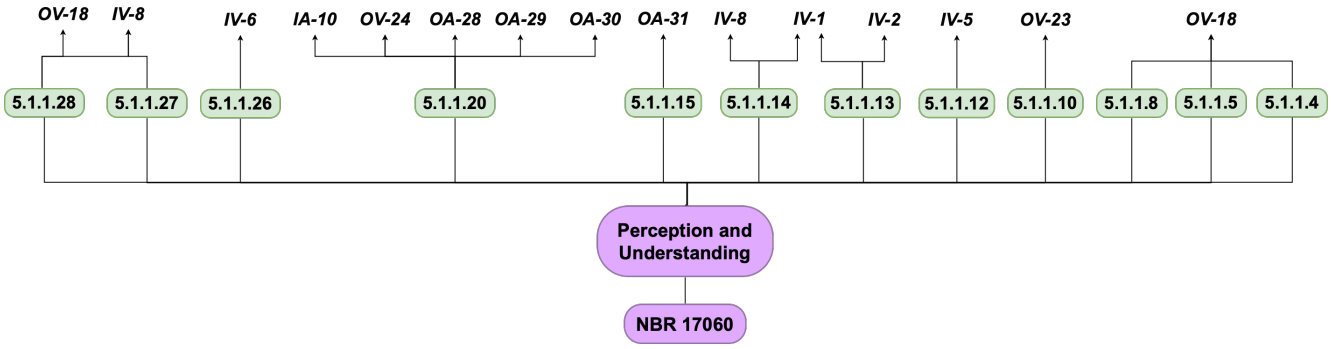

Figure 14. Comparative analysis of design and evaluation considerations with perception and understanding requirements and recommendations

Table 6. Sections not covered in the Perception and understanding category of NBR 17060:2022

Section	Description
5.1.1.1	Non-textual elements must have an alternative text that describes their meaning
5.1.1.2	It is recommended that texts be used instead of images
5.1.1.3	It is recommended that purely decorative elements that distract the user while performing the task are not used
5.1.1.9	It is recommended that the same visual pattern be maintained throughout the application
5.1.1.16	Interface elements of sequential items or that require pagination must situate the user
5.1.1.17	Texts and graphic elements must have sufficient contrast with their respective backgrounds
5.1.1.18	Color should not be the only way to convey information
5.1.1.19	There cannot be instructions that depend only on the user's sensory characteristics
5.1.1.22	All attempts at unavailable, inactive, or prohibited actions have feedback or feedback perceived by all users and assistive technology resources
5.1.1.23	A title must be programmatically describing the purpose of the pages and applications
5.1.1.24	Application languages must be declared
5.1.1.25	There should be an option to bypass flashing elements

Table 7. Sections of NBR partially related in category perception and understanding

Section	Description	Relation	Study III
5.1.1.6	The same organization of functional elements and accessible names must be maintained throughout the application	Positive	IV-8
5.1.1.7	Accessible names must contain the element labels	Positive	IV-8
5.1.1.11	Form field labels must be positioned in the usual way	Positive	OV-23
5.1.1.21	The application must provide a noticeable exit or return to all users	Negative	OV-25

7.1.2 Control and Interaction

Control and interaction is the category of NBR 17060:2022 ABNT [2022] responsible for guiding the development of mobile applications, in the creation of accessible resources. In this context, the complement of questions in this category resulted in accessible user interaction with the interface. In Figure 15 the intersections of design and evaluation considerations with the control and interaction category are shown.

The design and evaluation consideration IV-4 correctly follows requirement 5.1.2.7 and recommendation 5.1.2.8, which control automatically initiated audios, which are voice assistants. Even though they are accessibility features, the user must have the power to control them, as improper use of these features, such as long audios started arbitrarily, can negatively influence the user experience.

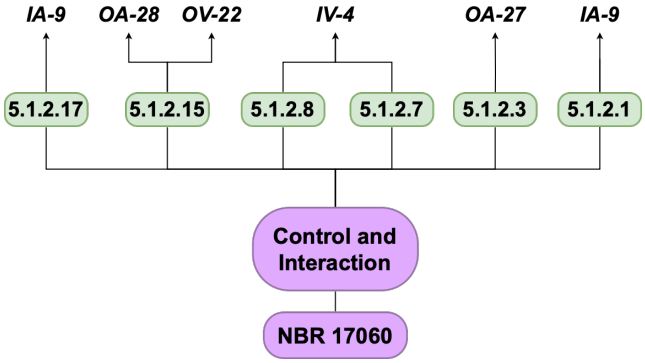

Figure 15. Comparative analysis of design and evaluation considerations with control and interaction requirements and recommendations

Design and evaluation consideration IA-9 suggests voice command control by screen taps or pronouncing keywords. Requirement 5.1.2.1 of NBR 17060:2022 explains the mobile device's native accessibility features. In this case, the application must provide the necessary resources based on the device's accessibility settings, providing more than one search possibility for the user. However, design and evaluation considerations do not include prior configuration of accessibility features on the device, with the aim that the mobile banking primarily offers accessibility features.

Design and evaluation consideration OV-22 indicates the user's ability to edit data fields before completing a task. Thus, OV-22 complies with requirement 5.1.2.15, which deals with indicating interaction errors.

Design and evaluation consideration OA-27 addresses customization of voice assistant app notifications, which is related to requirement 5.1.2.3, which indicates the ability to configure app notifications.

Design and evaluation consideration OA-28 proposes providing voice feedback to indicate alerts or errors about reported data, which corresponds to requirement 5.1.2.15, which deals with the indication of interaction errors and the possibility of error correction by the user.

Similar to the perception and understanding section, some recommendations in the control and interaction category of NBR 17060 are not linked to design and evaluation considerations, indicated in Table 8, and two requirements are linked partially, as shown in Table 9.

7.1.3 Media

The third category of NBR 17060:2022 ABNT [2022] is Media, which deals with alternative ways to understand non-

Table 8. Sections not covered in the Control and interaction category of NBR 17060:2022

Section	Description
5.1.2.2	There must be user control over mobile device movement actions
5.1.2.4	The user must be warned whenever forcing the device into a certain orientation (portrait or landscape) is necessary
5.1.2.5	It is recommended that the user's screen orientation not be restricted to a single orientation
5.1.2.9	There must be user control to pause, stop, or hide content that moves on the screen
5.1.2.10	There cannot be unexpected context changes when interacting with forms
5.1.2.11	There cannot be unexpected context changes when focusing on interactive elements
5.1.2.12	Every interaction must be supported by a single touch on the screen. If applications require multiple touches or specific gestures, a way must exist to allow the user to perform the same action with a single touch
5.1.2.13	It is recommended that interactive elements have a minimum touch area size
5.1.2.16	There must be support for enlarging the screen without losing information or functionality
5.1.2.18	It is recommended that list or table interfaces allow sorting
5.1.2.19	It is recommended that search engines be used in applications with large amounts of information

Table 9. Sections of NBR partially related in category control and interaction

Section	Description	Relation	Study III
5.1.2.6	There must be sufficient time for the user to perform the activities	Positive	IA-12
5.1.2.14	There can be no blocking in sequential navigation with assistive technology features	Positive	IV-4, IA-9, IA-10, OA-27, OA-28, OA-29, OA-30, OA-31, IOVA-33

textual elements, such as videos and audio, which may have complex or inaccessible content for people with specific characteristics. Therefore, providing multiple communication resources for non-textual elements is essential for the application to be accessible. However, Table 10 shows that the six requirements and recommendations in this category do not address any of the 33 design and evaluation considerations.

Table 10. Sections not covered in the Media category of NBR 17060:2022

Section	Description
5.1.3.1	Videos must offer subtitles for audio content
5.1.3.2	There must be at least one alternative resource for all pre-recorded video content, such as transcription or audio description
5.1.3.3	There must be a verbatim transcription for pre-recorded audio content
5.1.3.4	It is recommended that there is a text alternative to live audio content
5.1.3.5	It is recommended that an alternative in Libras be made available for audio content
5.1.3.6	Extended audio description is recommended for pre-recorded video content

7.1.4 Codification

Coding is the fourth category of NBR 17060:2022 ABNT [2022] and is aimed at good practices in building source code. She suggests that the order be placed according to the standards established by the developed technologies. In Web applications, the values must be correctly defined in the attributes of the tags that create the site's appearance to be identified by accessibility features. No specific design and evaluation considerations address accessibility features related to source code.

8 Inspection of Banking Chatbots

The main objective of chatbots is to achieve communication between humans and machines through AI. The machine simulates a human conversation, and repetition improves results to develop skills for more complex and effective responses.

Chatbots can be classified into two main aspects: declarative and conversational. Declarative chatbots are task-oriented, using natural language processing and machine learning to generate automated responses, commonly used in support services, defined through pre-defined responses without the possibility of variable reactions. Conversational chatbots are data-driven and predictive, grounded in natural language understanding, natural language processing, and machine learning to learn. In this context, they are used in digital assistants to learn the user's preferences and define a profile; it can also trace this data with other assistants and even anticipate it, providing suggestions and recommendations to the user Oracle [2024].

This article highlights the importance of using chatbots for emerging users, as they allow instant payment systems usage for people with low literacy, making digital financial services more accessible. With this, three questions were substantiated to direct the assessment of this service in five financial institution:

Q1 - Does mobile banking encompass conversational chatbot features?
Q2 - Do financial institutions provide conversational chatbots in the instant messaging application (Whatsapp)?
Q3 - Does the banking chatbots have a voice search engine?

In this scenario, the inspections were based on the three questions about chatbots (Q1, Q2, and Q3) of the same five financial institutions of mobile banking presented in Table 11.

Table 11. Comparison of chatbots in the mobile banking

Name	Q1	Q2	Q3
Application A	No	No	No
Application B	Yes	Yes	Yes
Application C	Yes	No	Yes
Application D	No	Yes	Yes
Application E	No	No	No

When inspecting Application A, there is no evidence of conversational chatbot in the features of the help menu (Q1) and banking chatbot in the WhatsApp (Q2). Therefore, the services available are unrelated to financial transactions, including Pix. Finally, voice search features are not provided in the mobile banking help menu and WhatsApp support (Q3).

About Application B, the conversational chatbot feature is available in the mobile banking (Q1) and banking chatbot is provided in the Whatsapp (Q2), allowing transfers via Pix, among other services. Likewise, the availability of the voice search feature in mobile banking and banking chatbot (Q3).

In Application C, conversational chatbot is provided in the mobile banking (Q1). However, there is no evidence of a banking chatbot on WhatsApp (Q2). Finally, the mobile banking allows users to perform a voice search (Q3); in this context, the user is redirected to frequently asked questions related to the indicated keywords or the task menu corresponding to the search.

In Application D, a virtual chat for human-to-human interaction is provided (Q1). On WhatsApp, the banking chatbot (Q2) is available; among the services available, it is possible to make transfers via Pix. Voice search is not available within mobile banking help chat. However, on WhatsApp, it is possible to search by voice (Q3).

Application E does not provide any conversational chatbot in its help menu. In this case, the help menu consists of questions and answers previously defined for mobile banking (Q1). Therefore, no evidence was found on the use of banking chatbot on WhatsApp (Q2). Therefore, the last question (Q3) is not answered in any of the cases.

9 Results

In this section, the data obtained in the two inspections are explored, using the design considerations [Teran, 2022], the design and evaluation considerations (Table 5). The data was obtained by comparing design and evaluation considerations with the Brazilian Technical Standard and investigating mobile banking and banking chatbots.

9.1 Test Result with Design Considerations

According to the visualization of the test results, as shown in Figure 16, Application C had the lowest rate of positive tests, with five tests. Then Application A had six positive tests, Application B had seven positive tests, Application D had nine positive tests, and finally Application E had ten positive tests. Application A had the lowest rate of partial results with four tests, followed by Applications B and E with five tests and C and D with seven tests each. Application A had the highest rate of negative tests, with 19 tests, followed by Applications B and C, with 17 tests each. Application E had 13 negative tests, and Application D had 12 negative tests. In Applications D and E, it was not possible to perform one of the proposed tests.

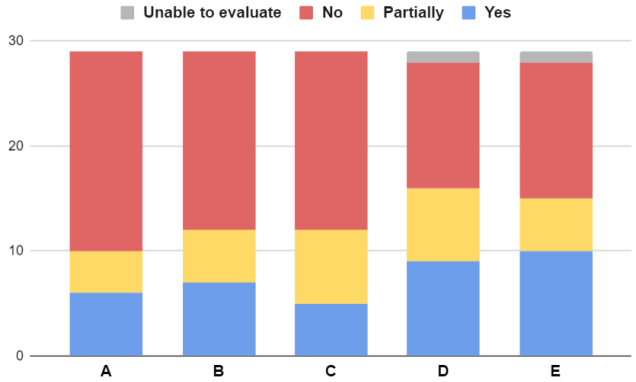

Figure 16. Analysis of results by application adapted from Melo *et al.* [2024]

In view of this, we can observe two aspects from the tests carried out with the design considerations [Teran, 2022]: the analysis of the design considerations based on their ordering, as well as the description of the evidence and verification of bias interpretation and accessibility assessment of mobile banking, based on the tests carried out and the results found.

The design considerations by Teran [2022], which condense the notes of Srivastava *et al.* [2021]; Thies [2015]; Randhawa *et al.* [2021]; Capra *et al.* [2021]; Gupta *et al.* [2022]; of Brazil [2022b]; Modesto and Ferreira [2013]; Tulaskar [2020], are focused on the design stage of interactive systems for emerging users and in this context, include instant payment applications and mobile banking. Therefore, it is interesting to group these studies and present a summary of the considerations aimed at accessibility inspection carried out by software developers. Furthermore, consideration descriptions can be evolved by presenting brief instructions for heuristic evaluations that can be performed by these professionals.

The descriptions of the design considerations are not easy to understand on first contact. When analyzing the present the keyboard corresponding to the data entry with the summary of design considerations, it was necessary to return to the specific details of the considerations for a better understanding, as well as reading the evidence to understand the cases that were applied in user tests. It was also noted that some design considerations in their description cited more than one improvement proposal, which generated bias in the interpretation and definition of the possibility of evaluation called “partial” in some tests. To better understand the application context, it was essential to map the descriptions and evidence of design considerations.

Among the five mobile banking tested, it was observed that none of them provided interface customization to improve access to resources provided by financial institutions. In some tests, it was necessary to modify the smartphone’s own settings to check the behavior of the applications, such as deactivating “silent mode”. It is worth mentioning that the considerations are focused on the development of accessibility for mobile applications, and even if smartphones and other mobile devices have in their operating system the accessibility feature available in the general settings, the application could provide the necessary accessibility features for its user’s clients, according to the proposal of design considerations [Teran, 2022].

One possibility that influenced the inspection carried out was the ordering of the design considerations [Teran, 2022]. Therefore, the considerations were focused on easy conception and application in the design phase and not in the inspection stages, which are directed to the product or service testing stage.

9.2 Results of Design and Evaluation Considerations

When analyzing the result of the second inspection carried out on mobile banking, this time using the 33 design and evaluation considerations, as shown in Figure 17, Application C had the highest partial result rate with three results, followed by Application B with two results and Applications A, D,

and E with only one partial result. The mobile banking with the highest rates of "no" results, both with 20 results, were Applications C and E, followed by Application D with 19 results, Application A with 18 results, and Application B with 17 results. With the result "yes", Applications A and B had the highest rates, with 14 results. Followed by Application D with 12 results, application E with 11 results, and Application C with 10 results. Applications D and E had the result "unable to evaluate".

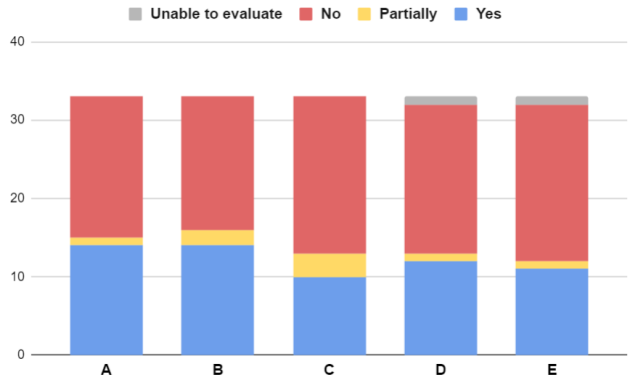

Figure 17. Analysis of results by application with design and evaluation considerations

Given the refinement of the design considerations by Teran [2022] and the proposals of improvement this framework presented by Melo *et al*. [2024], they were reorganized and categorized according to the Data Input and Data Output functionalities, as well as Audio and Visual resources, the tests carried out were optimized related to the flow of use of design and evaluation considerations, preventing tests from being redone due to being mentioned more than once and solving the problem of bias in the interpretation of design consideration descriptions [Teran, 2022].

However, it is still evident the visualization of tests with "partial" results, which had a higher result rate in the inspection with Teran [2022] design considerations, compared to the second inspection sequence, using the 33 design and evaluation considerations.

The comparison parameters of the inspections about the design considerations [Teran, 2022] and the design considerations and evaluation (Table 5) cannot be carried out since the refinement of the considerations did not maintain the previous classification, which in this case could highlight interpretation bias in the results.

9.3 Comparing of NBR 17060:2022 with Design and Evaluation Considerations

The comparing of design and evaluation considerations with NBR 17060:2022 had 16 design and evaluation considerations related to NBR 17060:2022 and 17 unrelated, totaling 33 design and evaluation considerations. NBR 17060:2022, with 54 requirements and recommendations, had 16 design and evaluation considerations and 38 unrelated. This data is shown in Figure 18.

Among the related design and evaluation considerations, two are in the data input and audio classification, five are in the data input and visual classification, five are in the data

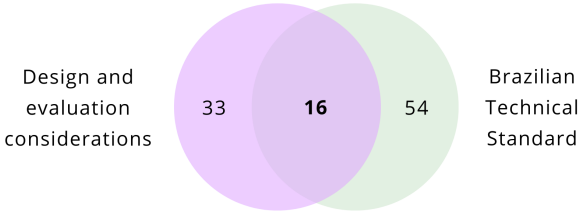

Figure 18. References design considerations and evaluation with the NBR 17060:2022

and audio output classification, and four are in the data output classification and visual.

We observed that 16 requirements and recommendations of NBR 17060:2022 are related to design and evaluation considerations, where 11 are in the perception and creation classification, and five are in the control and interaction classification. As a result, approximately 38 requirements and recommendations have no relation to design and evaluation considerations.

The relationship between design and evaluation considerations with the Brazilian Technical Standard is low, indicating 13,92% when relating the average percentage of the values noted in Figure 18. As design and evaluation considerations with the requirements and recommendations of the Brazilian Technical Standard may be related more than once, this value cannot be considered absolute.

9.4 Inspection of Banking Chatbots

Among the five financial institutions observable (Figure 19), only one mobile banking answers all questions about chatbots, followed by two mobile banking that answer 66.66% of the questions about chatbots, and the other two mobile banking inspected do not answer any questions about chatbots.

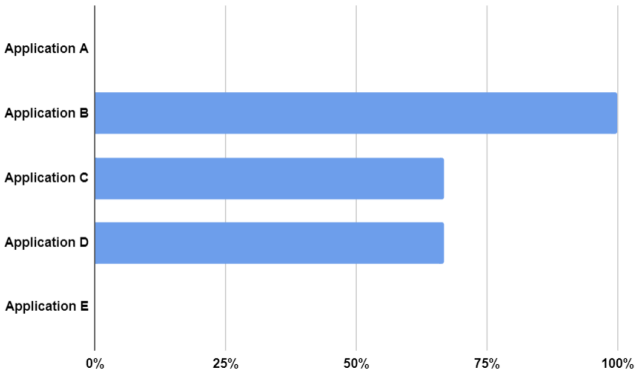

Figure 19. Percentage of questions answered about chatbots

There is no evidence of AI use in the documentation and news in Application A. When inspecting the banking chatbot and, specifically, the help menu in WhatsApp, we perceived only the interactions by pre-defined questions. Thus, this is similar to the concept of a declarative chatbot.

In Application B, the banking chatbot has more evident attention and interest, positively, answering the three questions about chatbots. However, when carrying out inspections with design and evaluation considerations, we observed that the audio features provided by the Android smartphone

are still not fully functional. As a result, the tests for the design and evaluation considerations scenario and the chatbot scenario were effectively carried out using the banking application on the iOS smartphone.

Application C provides the conversational AI service, however when using the voice search feature in the application, the search result behavior is consistent with task-oriented search, as the user is redirected to the task menu corresponding to the keyword indicated in the search. We also observed that the services available are related to common service queries such as balance and statement, without the availability of the Pix service.

Application D provides several services in the Whatsapp chatbot, including Pix. However, among the apps inspected, this is the only app whose help menu is 100% human-supported. Therefore, this service is available at a specific time and is subject to waiting for attendant availability.

The Application E does not provide conversational AI in the mobile banking, and the help menu available condenses a set of pre-defined questions and answers. When analyzing the mobile banking, it is reported that the use of AI resources is aimed at credit analysis for the user.

10 Discussion

This section presents the reflections on the use of the design considerations [Teran, 2022], and design considerations and evaluation (Table 5). The section also highlights comparing design and evaluation considerations with the Brazilian Technical Standard and the learning of banking chatbot inspections.

10.1 Observations about Design Considerations Usage

Through design considerations usage, it was observed that some considerations had more than one functionality that needed to be inspected. In other words, when a test in this case was carried out, and part of the proposed design consideration was met, and the other was not met, occasionally the test result was considered to be "partially", which is possible to observe with great relevance in the Figure 2. With this, it was possible to assume interpretation bias in the description of the consideration, and the possibility of assertively identifying errors was needed to detach more than one functionality to be evaluated in design consideration.

Based on the evidence obtained through the inspection of design considerations in mobile banking, to optimize the descriptions that suggest it and use them in applying heuristic evaluations, the design and evaluation considerations of instant payment applications were reclassified into four dimensions: Interface Consideration (CI), which corresponds to the application's functionality; Visual Consideration (CVis), which corresponds to interaction events on the application screen to understand the execution of the task better; Voice Consideration (CV), which corresponds to functionalities for performing tasks by voice and; Audio Consideration (CA), which consists of considerations related to the interpretation of functionalities or reading of data through audio. The ordering of considerations is characterized according to the need to implement and validate the functionalities in the applications to be tested. The restructuring of design considerations is shown in Table 3 in the work of Melo *et al*. [2024].

10.2 Observations of Design and Evaluation Considerations Usage

From the inspection with the design and evaluation considerations, which contemplate the refinement of the design considerations by Teran [2022] and the proposals by Melo *et al*. [2024], were fundamental to obtaining the results with greater precision, reducing the number of tests with "partial" results, caused by interpretation bias and grouping of features described in the same consideration.

Likewise, the design and evaluation considerations that still had a "partial" result are related to the descriptions of their functionalities. They also result from the inspections, where some evaluated resources are not standardized across all screens or tasks.

Therefore, with the decrease in "partial" outcome testing, there has been a considerable increase in "no" and "yes" outcome design and evaluation considerations, which are more visible for the "no" outcome. With this, we highlighted the importance of separating design considerations that were grouped with different functionalities, where we analyzed the results of the inspections more clearly.

The reorganization of classifications resulted in a positive impact related to the flow of tests. In the first sequence of tests, some tests had to be carried out more than once because they were repeated within the classification scenario made by dimensions. The new classification, related to audio and visual features and data input and data output features, makes it easier to overview design and evaluation considerations and in which aspects they can be found within the test scenario in mobile banking.

Regarding mobile banking updates, which occur according to the need for new implementations of banking systems and problem corrections, as well as updating the layout and reorganization of tasks and menus, we observed that new functionalities that are linked to design and evaluation considerations, such as voice search in banking applications, were implemented and validated in the second sequence of inspections, resulting in the contribution of "yes" results.

Finally, we highlight that reviews of design and evaluation considerations are pertinent and necessary. New insights from mobile banking updates and the exchange of experiences between HCI professionals contribute to improving descriptions and refining design considerations and evaluation, making mobile banking increasingly accessible.

10.3 Evaluation of Comparisons

The analysis carried out between NBR 17060:2022 ABNT [2022] and design and evaluation considerations indicates the points of intersection between them that, when relating these two artifacts, we note that 38 requirements and recommendations of the Brazilian Technical Standard in question

do not were related to design and evaluation considerations, representing more than 70% of the total.

Brazilian Standard 17060:2022 ABNT [2022] offers a variety of requirements and recommendations to make mobile applications, native or operated in a Web environment, simultaneously or independently, accessible to users. However, the guidelines presented are defined for general cases without considering the focus of the application. Therefore, NBR 17060:2022 does not include some specificities about design and evaluation considerations, which are oriented toward mobile banking.

Likewise, some design and evaluation considerations do not meet requirements or recommendations. This may be a consequence of the general modeling proposed by NBR 17060:2022 and the specificity of the context in which design and evaluation considerations are based. For example, the design and evaluation consideration that proposes the provision of a virtual agent to help the user in the mobile banking is not covered by NBR 17060:2022.

10.4 Inspection of Banking Chatbots

When analyzing the interaction with conversational chatbot in mobile banking and banking chatbots in the WhatsApp, we observed that design and evaluation considerations IV-3, IV-4, IV-6, IV-8, IA-9, IA-10, IA-11, IA-12, OV-16, OV-23, OV-26, OA-27, OA-28, OA-30, and IOV-32 are considered for this context. However, it is necessary to establish more inspection criteria for chatbots since this service still needs to be explored in the scenario of mobile banking, as it is evident that only 20% of the applications operated meet the questions about chatbots proposed in this work.

However, we observed that the in-app conversational chatbot scenario behaves differently in the Whatsapp instant messaging app, as the apps have different contexts. Therefore, a more careful analysis is necessary to define new design and evaluating considerations to evaluate banking chatbots.

In the work of Machado *et al*. [2023], users of mobile banking and physical banks reported in their responses that traditional banks convey more security when reporting data than digital banks. With this, we observed that in Applications B and D, which include conversational chatbot services on Whatsapp, with the provision of banking services, including transfers via Pix, in none of the applications security validation carried out when completing this task either authentication via password or the user's bank account or smartphone account, as well as user voice validation, because the security of the account linked to the chatbot is maintained by the number registered in the user's mobile banking. In this context, we observed that chatbot features do not meet the IA-11 and OV-26 design and evaluation considerations that deal with security validations.

10.5 Threats to validity

Two authors carried out the two sequences of inspections to refine the test descriptions and avoid interpretation bias. However, we observed that more authors could have contributed to the inspections for further refinement when carrying out the tests.The smartphones used in the tests and 80% of the bank app accounts inspected belonged to the authors, with Android and iOS operating systems in their latest version. However, the versions of smartphones and operating systems may not correspond to the reality of a person with low literacy, where banking applications may have version variations for operating systems in less recent versions.

With the two sequences of tests carried out, updating applications implies reorganizing design considerations and the possibility of creating new considerations based on new functionalities in banking applications.

11 Final Remarks

In this work, two design inspections were carried out on mobile banking and banking chatbots of five financial institutions, with the design considerations by Teran [2022] and the design and evaluation considerations presents in the Table 5, in which different data were collected based on the test scenarios. The comparing of design and evaluation considerations was also carried out with NBR 17060:2022 on accessibility in mobile applications and, finally, investigating the banking chatbots.

The result of the refinement of design and evaluation considerations by authors Melo and Teran did not generate new considerations. However, there is still a need to consider the guidelines in the Media and Codification categories of NBR 17060:2022. On the one hand, these NBR categories cover the accessibility of mobile applications in general, supporting the development of mobile applications in many elementary ways. On the other hand, design and evaluation considerations focus on a more restricted context, mobile banking.

Difference between tests performed with design considerations and design and evaluation considerations, wherein the first test scenario 53.8% of tests were not met by design and evaluation considerations. In the second test scenario, 56.97% were not met. Among the other tests, 25.5% of the tests had design considerations met in the first scenario; in the second test scenario, 37% of design and evaluation considerations were met, showing an increase in design and evaluation considerations served. Tests with partial results had a reduction, with 19.3% of design considerations partially met in the first test scenario and, in the second test scenario, 4.82%. The test scenario that was impossible to evaluate remained in two tests, representing 1.4% in the first scenario and, in the second, 1.20%.

The "no" results represented more than half of the tests in both scenarios. This failure reinforces the reflection on how emerging users, especially people with low literacy, are still on the margins of the disruption that generates barriers to accessing ICTs, noting that accessibility in software development is not a priority.

The comparing of design and evaluation considerations reflects the importance of complying with the requirements and recommendations of NBR 17060:2022 on accessibility for mobile devices. The aim is to consolidate accessibility criteria for all contexts, including the emerging users addressed in this work.

AI resources favor accessibility, as they enable learning of the user's profile and make tasks easier to carry out. How-

ever, most mobile banking inspected still lack effective conversational chatbots for emerging users.

We observed that the use of help resources for emerging users, in the context of people with low literacy, is still flawed. The resources made available are not always accessible to the public in question, either due to lack of availability in the application or the lack of possibility for user interaction to contextualize the task to be performed. Therefore, it is justifiable to continue this research based on the results found, which are inconclusive, with the proposal of a starting point for inspecting and evaluating software seeking accessibility.

The application of tests using a persona, with characteristics inherent to people with low literacy, contributes to designers' and developers' reflections on understanding the difficulties faced by these users. It also strengthens the importance of accessibility throughout the software process, considering emerging users, to make applications equitable and effective in people's lives, regardless of access barriers.

The contribution of this research occurs in four aspects: (i) it can be stated that the most used mobile banking in the country have barriers in accessibility for users with low literacy; (ii) it was possible to improve the design considerations used to inspect applications; (iii) the Brazilian Technical Standard is generalized for mobile applications and does not address emerging users, so it has yet to be explored regarding the financial scenario; therefore, it would be interesting if the technical standards were separated into blocks of scenarios to be implemented to examine their specificities, including design and evaluation considerations and other considerations to be reflected according to new tests and new evidence; (iv) chatbots still emerge in the main Brazilian mobile applications, which are necessary to make digital financial services more accessible; however, safety issues in use need to be reinforced.

It is necessary to consider design and evaluation considerations in the daily lives of software development professionals as a basis for implementing improvements in instant payment applications to make them secure and maximize access to information for low literacy users.

In future work, it is suggested that other instant payment applications be checked to validate the design and evaluation considerations, analyze the proposals, carry out the tests, and validate the considerations for the adequacy of the communicability of the applications to make them accessible. In addition, the improvement of design and evaluation considerations by NBR 17060:2022, with other professionals in the development area, as well as HCI specialists, for effective alignment of the proposals of this work, in the application of the method quickly and low learning cost, seeking necessary improvements through interaction with design professionals, software developers, and other people responsible for the development area.

Furthermore, these design and assessment considerations can be used in HCI classes to strengthen students' critical thinking about accessibility issues and encourage this quality direction for future professionals. Finally, it is recommended to reflect on mapping specific design and evaluation considerations for chatbots, considering the scenario of instant messaging applications, and for Web banking systems, which remains practical for banking transactions.

Declarations

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Authors' Contributions

GLNM: data curation, formal analysis, investigation, methodology, project administration, visualization, writing – original draft. RPM: data curation, formal analysis, visualization, writing – original draft. NSM: formal analysis, visualization, writing – original draft. LAT: data curation, formal analysis, investigation, validation, visualization, writing – original draft. MPM: methodology, supervision, validation, writing – original draft, writing – review and editing. All authors read and approved the final manuscript.

Competing interests

The authors declare they have the following competing interests.

Availability of data and materials

All supplementary material generated in inspections and comparisons in this article is available at Melo [2024].

References

ABNT (2022). Associação brasileira de normas técnicas. https://www.abntcolecao.com.br/mpf/default.aspx?T=9BC37A821F0D. Access on 08 August 2024.

Aquino, P. T. and Filgueiras, L. V. L. (2008). A expressão da diversidade de usuários no projeto de interação com padrões e personas. In *Proceedings of the VIII Brazilian Symposium on Human Factors in Computing Systems*, IHC '08, page 1–10, BRA. Sociedade Brasileira de Computação. Access on 08 August 2024.

Aribandi, A., Agrawal, D., and Chakraborty, D. (2022). Note: Evaluating trust in the context of conversational information systems for new users of the internet. In *Proceedings of the 5th ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies*, COMPASS '22, page 574–578, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/3530190.3534852.

Baranauskas, M. C. C., de Souza, C. S., and Pereira, R. (2012). Grandihc-br: prospecção de grandes desafios de pesquisa em interação humano-computador no brasil. In *Companion Proceedings of the 11th Brazilian Symposium on Human Factors in Computing Systems*, IHC '12, page 63–64, Porto Alegre, BRA. Brazilian Computer Society. Access on 08 August 2024.

Brazil (2014). emag - modelo de acessibilidade em governo eletrônico. https://emag.governoeletronico.gov.br/. Access on 08 August 2024.

Capra, E. and Ferreira, S. (2023). Acessibilidade web para cuidadores analfabetos funcionais: reflexões sobre o uso de tecnologias voltadas ao trato do idoso. *Brazilian Journal of Information Science: research trends*, 17:e023021. Access on 08 August 2024. DOI: https://doi.org/10.36311/1981-1640.2023.v17.e023021.

Capra, E., Ferreira, S., Marques, J. M., and Portela, S. (2021). Acessibilidade de interfaces web para cuidadores com baixa escolaridade: Aspectos e reflexões. *Conexões - Ciência e Tecnologia*, 15:e021026. Access on 28 May 2023. DOI: https://doi.org/10.21439/conexoes.v15i0.2087.

Central Bank of Brazil (2023). Ranking de reclamações. https://www.bcb.gov.br/ranking/index.asp?rel=outbound frame=1. Access on 08 August 2024.

Central Bank of Brazil (2024). Acessibilidade no pix. https://www.bcb.gov.br/estabilidadefinanceira/acessibilidadepix. Access on 08 August 2024.

Chat2Desk (2022). Chatbots já superam humanos em atendimento bancário. https://chat2desk.com.br/blog/chatbots-ja-superam-humanos-em-atendimento-bancario/. Access on 08 August 2024.

da Costa Nunes, E. H. and Monteiro, I. T. (2024). Exploring the accessibility legal landscape: Accessibility requirements in mobile applications according to abnt nbr 17060. In *Proceedings of the XXII Brazilian Symposium on Human Factors in Computing Systems*, IHC '23, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/3638067.3638121.

Devanuj and Joshi, A. (2013). Technology adoption by 'emergent' users: The user-usage model. In *Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction*, APCHI '13, page 28–38, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/2525194.2525209.

FEBRABAN (2023). Bancos deixarão de oferecer transferências via docs até fevereiro de 2024. https://portal.febraban.org.br/noticia/3926/pt-br/. Access on 08 August 2024.

Fernandes, A. (2023). Por que falta acessibilidade para pessoas com deficiência visual nos aplicativos de celular? https://mwpt.com.br/por-que-falta-acessibilidade-para-pessoas-com-deficiencia-visual-nos-aplicativos-de-celular/. Access on 08 August 2024.

Filgueiras, L., Martins, S., Tambascia, C., and Duarte, R. (2009). Recoverability walkthrough: An alternative to evaluate digital inclusion interfaces. In *2009 Latin American Web Congress*, pages 71–76. Access on 08 August 2024. DOI: https://doi.org/10.1109/LA-WEB.2009.32.

Følstad, A., Nordheim, C. B., and Bjørkli, C. A. (2018). What makes users trust a chatbot for customer service? an exploratory interview study. In *Internet Science: 5th International Conference, INSCI 2018, St. Petersburg, Russia, October 24–26, 2018, Proceedings 5*, pages 194–208. Springer. Access on 08 August 2024. DOI: https://doi.org/10.1007/978-3-030-01437-7_16.

Gupta, M., Mehta, D., Punj, A., and Thies, I. M. (2022). Sophistication with limitation: Understanding smartphone usage by emergent users in india. In *ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies (COMPASS)*, COMPASS '22, page 386–400, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/3530190.3534824.

Jeffries, R. E., Anderson, A., and Hendrickson, C. (2000). *Extreme Programming Installed*. Addison-Wesley Longman Publishing Co., Inc., USA. Access on 08 August 2024.

Lopes, R., Façanha, A. R., and Viana, W. (2022). I can't pay! accessibility analysis of mobile banking apps. In *Proceedings of the Brazilian Symposium on Multimedia and the Web*, WebMedia '22, page 253–257, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/3539637.3558048.

Machado, A., Menezes, S., Lopes, J., Santos, J., Porfirio, I., Cruz, C., and Nascimento, B. (2023). Bancos físicos x digitais – evolução tecnológica nos serviços bancários. In *Anais do XX Congresso Latino-Americano de Software Livre e Tecnologias Abertas*, pages 55–61, Porto Alegre, RS, Brasil. SBC. Access on 08 August 2024. DOI: https://doi.org/10.5753/latinoware.2023.236468.

Medhi, I., Patnaik, S., Brunskill, E., Gautama, S. N., Thies, W., and Toyama, K. (2011). Designing mobile interfaces for novice and low-literacy users. *ACM Trans. Comput.-Hum. Interact.*, 18(1). Access on 08 August 2024. DOI: https://doi.org/10.1145/1959022.1959024.

Melo, G. (2024). Open science inspecting banking chatbots. https://github.com/human-interaction-with-tecnologies/open-science-inspecting-banking-chatbots. Access on 08 August 2024.

Melo, G. L. N., Menezes, N. D. S., Da Silva, I. M. M., Teran, L. A., and Mota, M. P. (2024). Inspecting the accessibility of instant payment systems from the perspective of low literacy people. In *Proceedings of the XXII Brazilian Symposium on Human Factors in Computing Systems*, IHC '23, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/3638067.3638127.

Ministério das Comunicações (2022). Celular segue como aparelho mais utilizado para acesso à internet no brasil. https://www.gov.br/mcom/pt-br/noticias/2022/setembro/celular-segue-como-aparelho-mais-utilizado-para-acesso-a-internet-no-brasil. Access on 08 August 2024.

Modesto, D. M. and Ferreira, S. B. L. (2013). Acessibilidade de recursos em uma interface de motor de busca com foco em usuários com baixo letramento. In *Proceedings of the 12th Brazilian Symposium on Human Factors in Computing Systems*, IHC '13, page 32–41, Porto Alegre, BRA. Brazilian Computer Society. Access on 08 August 2024. DOI: https://doi.org/10.5555/2577101.2577112.

Moreira, C. (2012). Letramento digital: do conceito à prática. In *Anais do SIELP*, volume 2, pages 1–15. https://www.ileel.ufu.br/anaisdosielp/wp-content/uploads/2014/06/volume_2_artigo_051.pdf.

Access on 08 August 2024.

Nery, F. d. C., Santos, A. P. d., Chicaroni, B. F., Braga, J. C., Brandáo, A. L., and Gois, J. a. P. (2022). Customization guidelines for mobile applications from a universal design perspective. In *Proceedings of the 21st Brazilian Symposium on Human Factors in Computing Systems*, IHC '22, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/3554364.3559120.

of Brazil, C. B. (2022a). O que é pix. https://www.bcb.gov.br/estabilidadefinanceira/pix. Access on 08 August 2024.

of Brazil, C. B. (2022b). Requisitos mínimos para a experiência do usuário. `https://www.bcb.gov.br/estabilidadefinanceira/pix?modalAberto=regulamentacao_pix`. Access on 08 August 2024.

Oracle (2024). O que é um chatbot? https://www.oracle.com/br/chatbots/what-is-a-chatbot/. Access on 08 August 2024.

Randhawa, S. M., Ahmad, T., Chen, J., and Raza, A. A. (2021). Karamad: A voice-based crowdsourcing platform for underserved populations. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/3411764.3445417.

SIDI (2019). Acessibilidade móvel guia para o desenvolvimento de aplicações móveis acessíveis. https://www.sidi.org.br/guiadeacessibilidade/#inicio. Access on 08 August 2024.

Srivastava, A., Kapania, S., Tuli, A., and Singh, P. (2021). Actionable ui design guidelines for smartphone applications inclusive of low-literate users. *Proc. ACM Hum.-Comput. Interact.*, 5(CSCW1). Access on 08 August 2024. DOI: https://doi.org/10.1145/3449210.

Tambascia, C., Ávila, I., Piccolo, L., and Melo, A. M. (2008). Usabilidade, acessibilidade e inteligibilidade aplicadas em interfaces para analfabetos, idosos e pessoas com deficiência. In *Proceedings of the VIII Brazilian Symposium on Human Factors in Computing Systems*, IHC '08, page 354–355, BRA. Sociedade Brasileira de Computação. Access on 08 August 2024. DOI: https://doi.org/10.5555/1497470.1497538.

Teran, L. A. (2022). Considerações de design para sistemas de pagamentos instantâneos e usuários emergentes. Master's thesis, Universidade Federal do Pará. Access on 08 August 2024.

Teran, L. A., Melo, G. L. N., Silva, I. M. M. d., Salles, R. B. d., Rocha, T. A. d., and Mota, M. P. (2024). A set of professional tools to support the design and evaluation of real-time payment systems and emergent users. *Journal on Interactive Systems*, 15(1):790–809. Access on 08 August 2024. DOI: https://doi.org/10.5753/jis.2024.4207.

Teran, L. A. and Mota, M. P. (2024). Design considerations for real-time payment systems and emerging users. In *Proceedings of the XXII Brazilian Symposium on Human Factors in Computing Systems*, IHC '23, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/3638067.3638107.

Thies, I. M. (2015). User interface design for low-literate and novice users: Past, present and future. *Foundations and Trends® in Human–Computer Interaction*, 8(1):1–72. Access on 08 August 2024. DOI: https://doi.org/10.1561/1100000047.

Tulaskar, R. (2020). Study of instructional illustrations on icts: Considering persona of low-literate users from india. In *Proceedings of the 2020 Symposium on Emerging Research from Asia and on Asian Contexts and Cultures*, AsianCHI '20, page 53–56, New York, NY, USA. Association for Computing Machinery. Access on 08 August 2024. DOI: https://doi.org/10.1145/3391203.3391217.

UNESCO (2018a). Designing inclusive digital solutions and developing digital skills. https://unesdoc.unesco.org/ark:/48223/pf0000265537. Access on 08 August 2024.

UNESCO (2018b). Digital inclusion for low-skilledand low-literate people. https://unesdoc.unesco.org/ark:/48223/pf0000261791. Access on 08 August 2024.

UNIFASE (2023). Letramento digital: o que é e como integrar corretamente a tecnologia ao ensino. https://www.unifase-rj.edu.br/letramento-digital-o-que-e-e-como-integrar-corretamente-a-tecnologia-ao-ensino: :text=O Access on 08 August 2024.

World Wide Web Consortium (2002). User agent accessibility guidelines 1.0. https://www.w3.org/TR/UAAG10/. Access on 08 August 2024.

World Wide Web Consortium (2023). Web content accessibility guidelines (wcag) 2.1. https://www.w3.org/TR/WCAG21/. Access on 08 August 2024.