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A Set of Professional Tools to Support the Design and Evaluation of Real-Time Payment Systems and Emergent Users

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Abstract: The popularization of the smartphone has generated new financial technology opportunities for our society. In Brazil, with the emergence of Pix in 2020, several people are migrating to this tool to obtain new payment and income acquisition forms. However, the social characteristics of people facing longitudinal barriers, access to formal education, and computational systems must be considered to improve digital and financial access. We aim to provide a web platform, called Inclue Platform to help software developers design and evaluate their real-time payment systems promoting emergent user inclusion. The research combined a set of methodological procedures: literature review, questionnaires, interviews, two case studies and a viability test. Software development professionals, a riverside community, and residents of an Amazonian city engaged in this study. The communicability assessment method was used in the case studies. The Include Platform viability test results suggest that it can be an effective support tool for software development professionals, although its content could still be improved.

Keywords: Digital accessibility, Financial services, Emergent users

1 Introduction

Several countries have introduced computerized payment technologies that meet the objective of improving the digital and financial accessibility of their population. In 2023, a total of 266.2 billion electronic payments were executed through the utilization of interactive systems worldwide. In India and Brazil, this represents a respective increase of 44.6% and 77.9% in real-time payment systems between 2022 and 2023 [ACI Worldwide, 2024]. Since then, there has been a growing take-up of real-time payment applications by the population of countries in the Global South.

Specifically in Brazil, the electronic transfer resources of financial institutions are unified in a digital transaction medium called Brazilian Real-time Payment, in Portuguese "Pagamento Instantâneo Brasileiro" or Pix, made available by Bacen in 2020 [Central Bank of Brazil, 2022b]. Since then, Pix began to add to the acquisition of income and payment management for Brazilians individuals and companies. Its acceptance among the Brazilian population was so significant that other traditional electronic transfer services, such as TED and DOC, were deactivated in early 2024 [Brazilian Federation of Banks, 2023].

The literature has shown that interactive web and mobile systems have been provided with several accessibility barriers [Mateus *et al*., 2021]. Then, while payment services, such as Pix, can provide new financial possibilities for the population of Global South countries, it is essential to remember that they must be inclusive for all inhabitants. Among them, the interaction characteristics of emergent users must be considered. These users, during their social experiences, have faced barriers to accessing formal education, have lower salaries, live in locations far from urban centers, and have unique cultural expressions and socio-environmental interactions [Devanuj and Joshi, 2013; Dhaygude and Chakraborty, 2021].

In the third quarter of 2022, the National Household Sample Survey, in Portuguese "Pesquisa Nacional de Amostra a Domicílios" or PNAD, estimated that there are 25.7 million self-employed workers in Brazil [IBGE, 2022]. Veloso *et al*. [2022] found that between 1992 and 2020, there was a reduction of self-employed workers who had between 0 to 8 years of studies, considered primary school grades. However, despite a significant increase in the informality rate of the professionals with formal education time over 12 years, the highest concentration of self-employed workers is still among citizens with 8 years or less of formal education.

In the case of self-employed workers, the lack of accessibility can devalue their personal or family income and generate fewer job opportunities, increasing the social inequality of a population. Referring to a population with emergent users, digital exclusion creates barriers to global social equality goals, as in the case of the 17 Sustainable Development Goals (SDGs) of the ONU's 2030 Agenda [ONU, 2015]. These challenges mainly affect the eighth, ninth, and tenth SDGs: decent work and economic development, industry, innovation, and infrastructure, and reducing social inequalities.

Medhi *et al*. [2011] presented evidence of interfaces that create barriers to accessing general or financial interactive

systems for emergent users, namely: complexity in the use of menu navigation, hidden functions at the navigation level, scroll bars that make interpretation difficult, lack of standardization of the keyboard and data entry in the interacted resources, absence of user-identified words, and large amounts of text in the help resources. Although the evidence presented by Medhi *et al*. [2011] is more than a decade old, their identified barriers are still recurrent in interactive systems, which shows the importance of building and using tools that support the development of payment applications accessible to emergent users.

Emergent users need to be included in access to financial services, as the relationship between customers and suppliers has increasingly migrated to the digital environment. Thus, to have financial accessibility and income acquisition in payment systems, digital accessibility must be strengthened. This research aims to provide a web platform, called Inclue Platform, to support software developers in designing and evaluating real-time payment systems for emergent users. This research connects with some of the goals in the 2030 Agenda and embraces contributions that can favor the reduction of digital and financial exclusion.

These objectives were met through five stages of methodological procedures. The first stage involved learning about the state-of-the-art and the practice of developing accessible software through systematic literature mapping, a questionnaire with professionals, and recommendations for emergent users.

In the second stage, an inspection of a bank application redesign and a case study with an Amazon riverside community was conducted. At the end of this stage, the first set of design considerations was generated.

In the third stage, a new case study was conducted with emergent users in a northeast city in Pará. Next, a set of 29 design considerations was generated and applied in an inspection study of five Brazilian bank applications. 33 design and evaluation considerations for real-time payment systems evolved from these inspections.

In the fourth stage, the Inclue Platform was built based on the results of the previous studies. The platform was developed with GitHub Copilot support and published on the internet[1]. The Inclue Platform presents a set of design and evaluation considerations, with descriptions and examples of resources that must be made available in interactive systems to strengthen access for emerging users, personas with the socio-digital characteristics of emerging users, and quiz for the developer to check their learning about design and evaluation considerations and emerging users.

Finally, in the fifth stage, an online questionnaire was administered to assess the viability of the Inclue Platform among software development professionals. Participants answered questions about their knowledge of accessibility, interacted with the Inclue Platform, and indicated the advantages or challenges they encountered during their interaction.

Regarding the results, the software development professionals indicated that they believe they develop accessible interactive systems and that the Inclue Platform has the potential to be a valuable tool for promoting the inclusion of emergent users. They recommended several improvements to enhance understanding and interaction with the Inclue Platform, which could reduce cognitive load and improve their professional tasks.

This article is an extended version of the paper in Portuguese entitled "Design Considerations for Real-Time Payment Systems and Emerging Users", published in the Proceedings of the XXII Brazilian Symposium on Human Factors in Computing Systems [Teran and Mota, 2024] (IHC 2023). In this extended version, the main contribution was to provide and evaluate a practical tool, the Inclue Platform, to support software designers and developers in real-time payment systems that are more inclusive for emergent users.

This article is divided as follows: section 2 presents the theoretical background; section 3 presents related work on design recommendations for emergent users and technical platforms for software development; section 4 presents the research method, as well as the stages and ethical aspects of the research; section 5 presents the results of the case studies conducted in a riverside community and in a city in the northeast of the state of Pará; section 6 presents the proposed solutions, divided into theoretical and practical tools for the inclusion of emergent users; the 7 section presents the results obtained through the viability study conducted with software development professionals; finally, the 8, 9 and 10 sections present the discussions, threats to validity and final considerations respectively.

2 Theoretical Background

To better understand this work, we delineate several areas of study, including the digital inclusion of emergent users, real-time payment systems, and semiotic engineering and communicability.

2.1 Digital Inclusion of Emergent Users

As computing continues to evolve, it becomes imperative to understand and address the specific needs of user groups who are often marginalized or encounter significant barriers when engaging with digital technologies. There are several challenges to ensure that the population uses the services incorporated in digital technologies, especially those mediated by public authority services, without facing segregation or economic and social vulnerability [Vieira and Andrade, 2024]. Digital inclusion transcends the narrative of merely proliferating Digital Information and Communication Technologies (DICTs), as a significant portion of technological advancements is tailored to the markets of the Global North [Bilal *et al*., 2019], primarily focused on the Western sphere, especially the experienced users [Dhaygude and Chakraborty, 2021].

Upon recognizing this digital disparity among users, researchers have coined the term "emergent users" [Devanuj and Joshi, 2013], which refers to groups characterized by lower educational levels, economic disadvantages, geographical dispersion, or cultural diversity [Bilal *et al*., 2019], as well as those who have had delayed access to digital technologies and possess low digital literacy [Dhaygude and

[1] Inclue Platform: `https://inclue.vercel.app/`

Chakraborty, 2021], considering that some users may also lag behind technological advancements due to their age group [Sengupta *et al*., 2017]. Analyzing these characteristics, it is evident that these groups mainly consist of the elderly, people with disabilities, individuals with low literacy or even low digital literacy, or those from backgrounds with limited access to DICTs, all of whom face various digital barriers in interacting with current interactive systems due to their limited or absent understanding of interface features [Devanuj and Joshi, 2013].

In a world that evolves through the mediation of DICTs, emergent users must deal with digital solutions that are coherent and flexible with their realities [Jones *et al*., 2017]. To address the absence of inclusive design, studies emphasize the importance and effectiveness of collaborative work through the creation of prototypes for these individuals in a highly participatory manner, as confirmed by Bidwell *et al*. [2010].

Thus, in the context of emergent users, individuals with disabilities, residents of rural areas, and inhabitants of nations in the global South are groups to benefit from this accessible perception [W3C, 2018]. It is assessed that among these groups, individuals with low literacy, i.e., people with limited reading and writing skills, constitute another specific user group that likewise needs to be included in interactive systems equitably, ensuring that the use of these services is both independent and safe [Teran, 2022].

As presented by Jones *et al*. [2017], assessing development solely to address illiteracy mitigates the problem precisely due to the social aspects involved, as it is understood that this user is surrounded by the assistance of others. IN order to accomplish this objective, prototypes are presented capable of highlighting these individuals' ideas about the interaction barriers encountered, wherein combined access techniques, for example, combinations of visual and text means on devices, deviate from the context of an emergent user with low literacy.

In the development of these DICTs, expecting interaction to be tangible becomes unsustainable given the availability of resources, as evaluated by Jones *et al*. [2017], where approaches to such interactions deal with forms of competencies centered on the culture of a developed occidental society. Proposals made through paper prototyping or through voice-activated digital assistants, as suggested by Bidwell *et al*. [2010], assist in the inclusion of these individuals in a more equitable manner, bringing aspects of experiences had by these users into an environment where resources and technological availability meet their needs.

2.2 Financial and Real-time Payment Systems

Financial systems play a fundamental role in the global economy, expressing various nuances regarding their organization and mission. On an international scale, according to a 2017 report by the World Bank, it was found that approximately 1.7 billion adults remain unbanked, unable to access basic financial services such as bank accounts or lines of credit [World Bank, 2018]. As a result, low-income populations in developing countries or rural areas, where the lack of financial and educational infrastructure creates significant barriers to accessing such services, are affected.

Evaluating through the Central Bank of Brazil (Bacen), the national financial system is composed of various institutions and entities, which perform vital functions such as financial intermediation, facilitation of payments and transfers, and provision of credit to individuals and businesses [Central Bank of Brazil, 2020]. The role of Bacen extends through financial citizenship, which also encompasses financial inclusion. According to Bacen's report [Central Bank of Brazil, 2021], it seeks to expand access to financial services for segments of the population historically excluded from the banking system, ranging from informal workers to low-income populations.

The advancement of DICTs has drastically transformed global financial systems, with real-time payments taking on significant prominence. Consequently, the operations of both digital and traditional banks are being updated to provide access to their various financial services through internet-enabled devices, such as smartphones [Ribeiro, 2020]. As a result, customers benefit from banking transactions with greater financial autonomy and convenience in their personal and professional activities.

Figure 1 indicates that the use of smartphones to make payments is lower as Brazilians' income is low, according to a report by Central Bank of Brazil [2021]. In the same study, data provided by the Brazilian Federation of Banks (FEBRABAN) indicated that 24% of internet users who use banking services, the mobile application is the most frequent channel for banking operations across all income brackets surveyed.

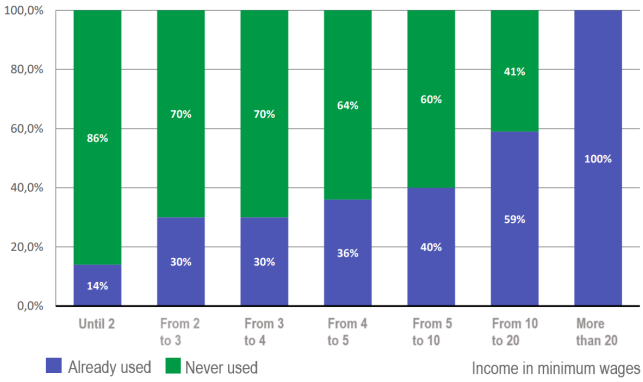

Figure 1. The use of smartphones for online payments [Central Bank of Brazil, 2021]

In Brazil, with the emergence of Pix in 2020, the real-time payment system developed by Bacen reflects an advancement in the financial landscape. According to recent data from the Bacen Report [Central Bank of Brazil, 2021], Pix has experienced exponential growth since its launch, with more than one billion Pix transactions conducted, moving over R$787 billion in transactions processed daily between the beginning of its operation and March 2021. This rapid adoption highlights the market demand for more efficient and accessible payment solutions.

In addition to its convenience, Pix aims to provide customers of financial institutions with a low-cost, secure, and appropriately interactive service [Central Bank of Brazil, 2022b]. With this goal in mind, Bacen has released artifacts to support developers and designers in the Pix usage adaptation, including a minimum user experience requirements

manual [Central Bank of Brazil, 2022c] and brand usage guidelines [Central Bank of Brazil, 2022a]. Consequently, these artifacts present various requirements that facilitate the construction of interactions suitable for users of financial institutions.

Thus, for digital inclusion through digital financial services, the study by Berdibayev and Kwon [2020] conducted analyses of models using data regression techniques and found that inclusion can be determined by Gross Domestic Product (GDP) per capita, availability of ATMs per adult, basic literacy skills, coverage of mobile internet tariffs, and 4G mobile coverage, political stability, and corruption control, categorizing these requirements as vital, important, and necessary to ensure this growth in access to digital systems.

2.3 Semiotic Engineering and Communicability

In Human-Computer Interaction (HCI), Semiotic Engineering evolves as a multidisciplinary term in the field, which, according to Leitão *et al*. [2013], has developed with authentic concepts and methods, centered on human communication mediated by computational systems. In this same context, Semiotic Engineering aligns with HCI when metacommunication occurs between a user and the system.

Adding to these concepts is the role of the designer, in which Semiotic Engineering [Barbosa *et al*., 2021] adds that the investigation is centered on communication among designers, users, and systems, occurring at two distinct levels: direct communication between the user and the system, and metacommunication from the designer to the user mediated by the system through its interface. Hence, the communication of an interactive system provided by designers to users is ensured through a software property called communicability, which is also considered a quality criterion used during system evaluation, as it can provide efficient and effective interactions to users and confidence in the developed projects [Prates *et al*., 2000].

Figure 2 illustrates the relationship of interlocutors in the communication process, namely users, systems, and designers, all involved in the same communicative process [Leitão *et al*., 2013]. During the construction of an interactive system, designers implement metacommunication in computational resources carefully evaluated based on studies with target audiences, ensuring an interactive experience for users of these systems.

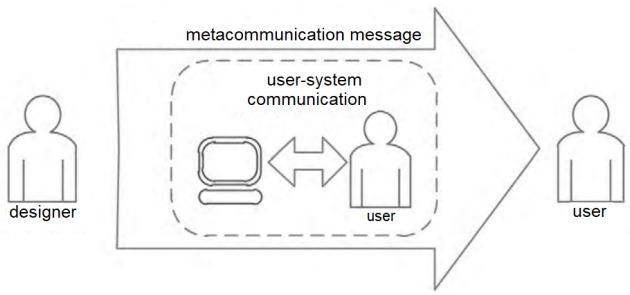

Figure 2. Communication process between designers, users, and systems [Barbosa *et al*., 2021]

Following the process of metacommunication, the interface in turn assumes the role of emitter, and from it, the user interacts with the system and receives the message constructed by the designer [Leitão *et al*., 2013]. As receivers, users must necessarily find the metamessages easily understandable to perform their tasks clearly.

Thus, communicability arises from the perception of how efficient and effective the communication proposed in the meta-message by its creators and developers to users can be. Therefore, in the communication process, sign developers use meaning systems to choose forms of representing their intended meanings to achieve a variety of objectives [Barbosa *et al*., 2021]. Consequently, artifact communication is appropriate when the constructed signs provide characteristics close to the signs of other meaning systems previously known by their receivers [de Souza *et al*., 2016].

In this context, in the communication process, sign developers use meaning systems to choose forms of representing their intended meanings to achieve a variety of objectives [Barbosa *et al*., 2021], considering that the system will be communicating computationally encoded meanings, once chosen by the designers. Therefore, the communication of an artifact is considered effective when the constructed signs provide characteristics close to the signs of other meaning systems previously known by their receivers [de Souza *et al*., 2016].

As a means of evaluating the communication of a system to validate whether an intellectual artifact possesses adequate communicability, HCI researchers focused on communication [de Souza *et al*., 1999, 2006; Oliveira *et al*., 2008; Villela *et al*., 2012; Carvalho *et al*., 2019] have developed methods that make it possible to assess the emission and reception of the metacommunication message. Two evaluation methods were used to develop this work: the Semiotic Inspection Method (SIM) and the Communicability Evaluation Method (CEM).

The two aforementioned methods of Semiotic Engineering, SIM and CEM, have their specificities. In the first case, SIM is an approach that can be used by HCI professionals to conduct inspection studies and evaluate the metacommunication message provided by designers in their developed systems [de Souza *et al*., 2006]. In the second case, CEM is an approach that provides HCI professionals with observation and analysis of user communication with the system by understanding the expectations, interpretations, approvals, and rejections of these potential users [de Souza *et al*., 1999].

Communicability can be considered as the intersection of these two evaluation methods of Semiotic Engineering. Because communicability is a property of software that presents the designers' aspirations for users to perform their tasks in the interactive system [Prates *et al*., 2000]. Thus, by applying these analysis methods, it is possible to measure the quality of the metacommunication message provided by designers to users through the interfaces presented in the interactive system [de Souza, 2005].

It is important to highlight that Semiotic Engineering works around ideal communication and does not focus on design aspects such as aesthetics, productivity, and user satisfaction [de Souza, 2005]. Thus, the theory provides an understanding of the interaction obstacles faced by users, providing considerations that enhance the communication of

these individuals with the system [Prates and Barbosa, 2007]. Semiotic Engineering correlates with accessibility guidelines by supporting designers in building accessible systems for the research target audience.

3 Related Work

Understanding artifacts closely related to the artifact of this research is essential for observing their contexts of use, the beneficiaries, the problems addressed, and the contributions provided. Therefore, the following subsections (3.1 and 3.2) highlight, respectively, some interactive design recommendations for the inclusion of emergent users and platforms supporting the design of accessible interactive systems presented in the state-of-the-art.

3.1 Interactive Design Recommendations for Emergent Users

After defining the target audience of the research as emergent users, searches were conducted for guidelines in the literature that provided recommendations for developing accessible interactive systems in studies focused on people with low literacy, low income, and traditional communities, so that the use of these recommendations would support design decisions in various usage contexts. Their importance lies in understanding which platforms and quality criteria are supported when using design bases validated by previous studies and, thus, building accessibility proposals in the financial usage context; and to identify the correlation of accessibility according to quality criteria, such as usability and communicability, to identify the absence of these criteria in the state-of-the-art of software development for emergent users.

Below are some of the studies that present design recommendations for emergent users, including people with low literacy, low income, and traditional communities.

Srivastava *et al*. [2021] conducted a Systematic Literature Review (SLR) to analyze the interfaces proposed by primary studies in the literature and to propose general interface recommendations for people with low literacy. Additionally, they also correlated the literature interfaces with recommendations proposed by some organizations between 2013 and 2020, such as: IDEO, Bill and Melinda Gates Foundation, Google, UNESCO, Microsoft, CGAP, and two others. As a result, the SARAL Framework was devised, containing 13 accessibility recommendations for people with low literacy categorized into 5 themes: input and output models, visual design, content and information architecture, help integration, and human loops.

Thies [2015] address the challenges faced by people with low literacy in using interactive systems. As results, the authors present a set of user interfaces that can support people with low literacy or digital novices in accessing various services mediated by ICTs. Thus, the authors indicate that instructional video resources can facilitate user interaction, provided they show executions close to the user's task, as well as the need to build paginated navigations to minimize the amount of information to be understood by the user, since presentations in deep hierarchies have lower performance, that is, navigations leveled through menus or other options that users need to use until they reach a desired action in the system.

Furthermore, the authors Thies [2015] also indicated that advances in VUI (Voice User Interfaces) have mitigated access disruptions to interactive systems, which were affected by grammar knowledge issues and device restrictions. VUIs are features that provide users with the ability to manage computational actions through voice interactions. The authors defined that this type of interface was difficult to implement on mobile devices for emergent users, given that they faced socio-environmental barriers to obtaining technological devices with the necessary requirements for VUI execution. This scenario has changed due to the popularization of smartphones and access to the internet.

Modesto and Ferreira [2013] conducted a two-stage study with people with low literacy to identify how they interact with search engine resources. Thus, a case study was divided into two stages of user behavior analysis. In the first stage, participants performed search tasks with different difficulty levels and objectives. In the second stage, five new participants performed two advanced search activities not used by previous participants during the first stage of the research, such as filters and advanced search. This enabled the authors to indicate 13 recommendations for developing accessible interfaces for people with low literacy.

Capra *et al*. [2021] conducted a systematic literature mapping with research published between 2000 and 2019 in the Scopus, ACM, and IEEE scientific databases. The exploratory research conducted by the authors aimed to identify contributions from primary literature studies that strengthen the accessibility of people with low literacy, specifically in the presentation of user interfaces that consider the interaction characteristics of caregivers of elderly people in accessing information services available on the internet. As a result, Capra *et al*. [2021] present six aspects that assist designers in building accessible systems for low literacy users.

The studies presented generate benefits for academia, industry, and consequently, their target audiences. To contribute to the evolution of HCI studies, this work differs from others by bringing the application of research including inspection and communicability evaluation techniques to improve the accessibility of emergent user groups. By considering communicability in the development of interactive systems, it is possible to include user culture in the process of designing interactive system interfaces and build satisfactory experiences that are in line with these individuals' sign understanding.

Furthermore, this is a study that provides social, financial, and digital inclusion for traditional Brazilian communities, more specifically for riverside people in the Amazon region, precisely by favoring the alignment of accessibility and communicability in the construction of interactions that meet tasks mediated by ICTs. By applying CEM from Semiotic Engineering to the analysis of interaction of emerging users in the financial scenario, it is possible to identify the disruptions of metacommunication of real-time payment systems and thus improve the interaction of riverside people with this type of service.

3.2 Platforms to Support the Design of Accessible Interactive Systems

Platforms for supporting design and evaluation of accessible interactive systems have emerged as essential tools in the development of interfaces that meet the needs of users with different abilities and usage contexts. These platforms offer resources and guidelines that enable designers and developers to create and evaluate interactive systems that are inclusive and accessible to all users, regardless of their physical, cognitive, or sensory limitations. In this related work subsection, recent contributions in the field of platforms supporting the design of accessible interactive systems are presented, highlighting progress and emerging trends in this area.

The following are works with design and evaluation recommendations available for accessible development in various contexts. These studies focused on some point of accessibility analysis, thus conducting a survey of recommendations through their research methods and seeking to make their materials and results available through online platforms to assist in various stages of interactive system development.

Valerio [2019] devised a tool motivated by the author's perception of the difficulties faced by various professionals in understanding the success criteria of WCAG and proposed a practical and innovative solution in the form of a platform called the "Accessibility Toolkit". The feedback highlighted the tool's relevance by showing that the success criteria are not limited to specific issues for individuals with disabilities, but as basic heuristics applicable to any digital project. As a result, the "Accessibility Toolkit" becomes an approach capable of representing the 78 success criteria of the WCAG in the form of manipulable cards online, making the topic more accessible and understandable for a variety of professionals involved in digital projects.

Another contribution was made through the GAIA Platform [Britto, 2016], which provides a guide of web accessibility recommendations specially developed to meet the specific conditions of people with autism. For the development of this work, the author initially analyzed the state-of-the-art through literature reviews, followed by online questionnaires with designers to understand their knowledge landscape regarding accessible development, and finally, interviews with parents of children with Autism Spectrum Disorder. As a result, ten categories of a set of recommendations for the development of interactive systems were obtained.

The Capian Platform [Capian UX-co, 2024] provides support for the design of accessible interactive systems, offering resources and tools aimed at facilitating the development of accessible interfaces for a wide range of users, including those with physical, cognitive, or sensory impairments. It provides designers with various use cases related to design guidelines linked to recommended accessibility practices, based on principles, criteria, and heuristics of the literature.With a user-centered and inclusive design approach, this tool plays a crucial role in promoting development focused on digital accessibility and user experiences.

It is possible to observe a concern regarding accessibility in interactive systems, as the available platforms aim to present and assist designers and developers with various methods and techniques in creating their projects. As an additional contribution, this work presents the Inclue Platform, which adopts a specific approach aimed at the design and evaluation of real-time payment systems, taking into account the conditions and characteristics of emerging users. These users, defined as individuals with low literacy, low income, and traditional communities, often face unique challenges in accessing and using digital financial services. Inclue, offers specialized resources and guidance to ensure that these users are adequately considered in the design and evaluation of real-time payment systems, thus contributing to greater financial and digital inclusion for these vulnerable groups.

4 Research Method

This is an applied research, since the knowledge acquired was incorporated into the construction of accessibility evaluation artifacts and the conception of instruments for designing and evaluating real-time payment systems for emergent users. The research has a qualitative-qualitative approach, as the experiences of emergent users, designers, and software developers were analyzed based on the numbers and generalization of the data collected. The methodological objectives are exploratory and descriptive. Initially, previous exploratory studies were conducted [Teran *et al.*, 2021b], to systematically map the literature and build up comprehensive knowledge on accessibility considerations in the software development process. Also a questionnaire was applied to collect developers' perspectives on the subject.

In addition to the exploratory nature, the state-of-the-art was surveyed to collect and observe the literature on accessibility in developing inclusive systems for emergent users. As for the descriptive aspect, two case studies were conducted with emergent users. The first case study was applied with riverside of the Legal Amazon[2] and the second case study conducted out in a northeast city located in the state of Pará.

Figure 3 summarizes five essential stages, the methodological procedures, to achieve satisfactory the contributions of the research. The materials built in the stages of this research can be found in a GitHub repository for open science and knowledge sharing; the access link is available at the footnote of this page[3] and the end of this paper.

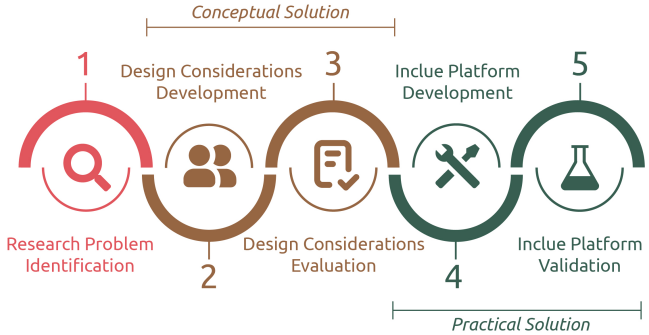

Figure 3. Research methodological procedures

[2]Legal Amazon: is a political term of law No. 5.173/1966, aimed at sustainable development, which encompasses 9 Brazilian Amazon states.

[3]Complementary materials: `https://bit.ly/open-science-eu-rtps`

The first three stages are preliminary studies, briefly presented in the subsections 4.1 and 4.2. They were used as a partial base for the development of new contributions. The last two stages (the fourth and fifth), through planning, building, and validating the Inclue Platform, present new methodological contributions to this research.

4.1 Research Problem Identification

The first stage was conducted in three distinct phases. Firstly, a systematic mapping was conducted, where studies on accessibility and its applications in developing interactive systems were collected. Secondly, a questionnaire was administered to software development professionals to understand how accessibility is implemented in their daily activities. More details about the methodology and results obtained in the first and second phases are presented by Teran *et al*. [2021a,b].

In the third phase, studies on the inclusion of emergent users were searched, from which some accessible design recommendations were also collected. The results showed studies on recommendations and interfaces of interactive systems in general, search engines, and internet services to emergent users (see Section 3.1).

The opportunity to research Pix as a tool for emerging users' financial and digital inclusion was identified by comparing the results of the three phases in this first stage. The Pix arose in 2020 to strengthen Brazil's electronic transaction connection. The importance of studying Pix for the inclusion of emerging users should be considered as a tool that reinforces the acquisition of income for various people in various contexts, among them Brazilian self-employed professionals who are primarily concentrated in people who face barriers in formal education [Veloso *et al*., 2022].

4.2 Design Considerations Development

The second stage was conducted in five distinct phases essential to constructing design considerations for including emergent users. More details of this research stage are presented by Teran *et al*. [2024].

In summary, a partnership was set up with a banking institution in the first phase of this research stage. A redesign of mobile banking was inspected using the Semiotic Inspection Method (SIM) [de Souza and Leitão, 2009], and Pix communicability breakdowns were captured.

In the second phase of this research stage, a prototype banking application was built with a medium level of loyalty. The functionalities of the prototype contained the primary Pix features: pay, receive, and create Pix key.

In the third phase of this research stage, a case study was carried out with 12 riversides from the Legal Amazon. The Communicability Evaluation Method (CEM) was used to identify and resolve communication violations [de Souza and Leitão, 2009]. The CEM steps were followed: planning, evaluating, analyzing results, reports, and recommendations.

The fourth phase analyzed the data obtained in the case study with riversides. In the fifth phase, initial design considerations for emergent users were generated.

4.3 Design Considerations Evaluation

The third stage involved validating and identifying improvements to the initial design considerations for real-time payment systems and emergent users. In the first phase of this stage, a high-fidelity prototype was created based on the Bacen manuals [Central Bank of Brazil, 2022a,c], the SIM report, the state-of-the-art and initial considerations generated in the case study with riverside people.

In the second phase of this stage, a new case study was conducted, in which 14 residents of a northeast city in the state of Pará. The CEM [de Souza and Leitão, 2009] was also used to identify and resolve the communicability breakdowns in the second phase. The steps followed were planning, evaluation, analysis of the results, reporting, and recommendations.

The third phase of this research stage involved validating and evolving the design considerations. After interpreting the second case study data, 29 design considerations were generated to include emergent users in real-time payment systems. More details about the methodology and results until the third phase of this research stage are highlighted by Teran and Mota [2024].

In the fourth phase of this research stage, the design considerations were applied in a practical accessibility inspection study of five Brazilian mobile banking apps that had the highest number of active customers as of the first quarter of 2023. After the inspections, the design considerations needed to be reorganized to improve its understanding and application while evaluating real-time payment systems for emerging users. More details this phase are presented by Melo *et al*. [2024].

In the fifth and last phase, the considerations were discussed to make them generic for designing and evaluating real-time payment systems and emergent users and refining them for a digital version. The considerations were redesigned by unifying the experiences of the two case studies and inspecting the five banking apps.

Three researchers worked on two refining meet cycles; in the first cycle, two primary authors of Teran and Mota [2024]; Melo *et al*. [2024] analyzed the categories and text of considerations, and in the second cycle, a third researcher participated to mediate the discussions and to expand the consolidation the results. 33 Design and evaluation considerations for real-time payment systems were defined to include emergent users.

The results of the first and second case studies contributed to the development of a conceptual solution—specifically, the design and evaluation considerations—to assist software designers and developers in creating accessible software. In other words, it is a document that can be used as a technical guide to strengthen the inclusion of emergent users in digital services, such as real-time payment systems.

4.4 Inclue Platform Development

In the third stage, the construction of the practical solution began to strengthen the digital inclusion of emergent users. A support tool was built for software designers and developers to use when designing and evaluating their systems.

First, the results obtained in the previous research stages

were analyzed to plan the platform's resources. The term "Inclue" was coined, and a total of 5 divisions were formulated: (i) start, (ii) personas, (iii) design and evaluation considerations, (iv) questions and answers, and finally (v) about. The details of each division and the objectives envisaged for the platform are analyzed in depth in the section 6.2.

From the platform concepts developed, a prototype was created in Figma to use as a basis for coding the project. The prototype was made available to the authors for possible refinements and redefinitions of ideas. This stage was followed by defining the project architecture and coding.

The platform was developed using the Next.js framework, which was coded by two programmers who are the authors of the article (the first and fourth authors). The project configuration management was done in the repositories of the source code hosting and version control platform Github.

The Inclue Platform was developed with the support of the intelligent programming assistant Github Copilot[4]. Github Copilot was used to support the development of accessible code. Furthermore, we used the Pa11y tool to collect accessibility violations, since the code was automatically generated by Copilot. In this context, accessibility problems were corrected by implementing the Framing [5] technique in Github Copilot input commands.

4.5 Inclue Platform Validation

The Inclue Platform was evaluated through viability tests with software development professionals. Thus, a form was made available divided into:

1. A presentation of the Free and Informed Consent Terms (FICT);
2. Questions on general information related to the professional activities carried out by the participants;
3. A test script, with the presentation of the interactions carried out by the participants;
4. Questions of Inclue Platform viability: content, organization, functionalities.

Ten questions were constructed using a Likert scale and open questions concerning the participant's professional activities. They were asked whether they were people with or without disabilities, their experience with software development, whether they developed resources with accessibility, and whether there was support from their organization or team to meet this quality criterion.

The test script was built with ten tasks so that participants could go through all the sections of the platforms. Some tasks highlighted specific interactions with the platform's content or functionalities.

Finally, 18 questions were constructed to evaluate the platform, structured on a Likert scale with open-ended questions. The questions were related to understanding and organizing the platform and specific sections.

[4]Github Copilot: `https://github.com/features/copilot`

[5]Framing: a concept that highlights feasible terms, such as accurate problem definitions, to accentuate communication texts.

4.6 Ethical Issues

The research was approved by the Research Ethics Committee (REC) of the Federal University of Pará, months before the case studies were conducted, whose Certificate of Submission for Ethical Appraisal (CAAE) was indexed to the number 54848021.8.0000.0018.

The first case study was conducted face-to-face in an Amazonian riverside community in March 2022. The technical team included a master's student and a volunteer researcher who acted as applicators and were responsible for organizing and observing the application of the case study. To participate as an applicator, an invitation was made one week before the case study was conducted, allowing them to explain the research details to riverside people and hand over the FICT.

When they handed in the FICT, the applicators asked the participants to read it over or to ask for help from people they trusted if any difficulty in understanding the content was faced, and after that, they could consent or not to the study. This allowed us to re-examine the content of the form and thus consider the importance of their participation in the research. To reinforce the subject, the FICT was re-explained before data collection to facilitate understanding or answer any questions the participants might have about the ethical aspects of the research.

Data collection took place in the participant's homes. It is important to highlight that the COVID-19 coping protocols were followed, using masks and alcohol gel for bilateral protection. The researchers and participants were preventively protected with at least two doses of the COVID-19 vaccine.

In November 2022, the second case study was done in a northeast city located in state of the Pará. The case study was conducted with just an applicator, who was responsible for managing and observing the interaction of the participants. The research and the FICTs were introduced to the participants two days before the study, where following the principles they had two days to read the document and realize if they had problems with the content presented. Then, during the days of the data collection, before the interviews and interactions, the applicator presented the FICT again to the participants, allowing them to indicate whether they still agreed to be interviewed for the research.

The viability study for the Inclue Platform was conducted using an online form with software development professionals. The first section of the form included the FICT, which the participants could read at any time and, after two days, consent to their participation in the study.

The project submitted to the REC included surveys of emergent users and software development professionals; this was necessary due to the need to collect data from various stakeholders in accessible software development. By employing this approach, we can identify the challenges encountered by users and development professionals, analyze their interactions with digital services, and enhance the solutions suggested by the research.

5 Case Studies with Emergent Users

As indicated in the methodology section, the research encompassed two studies: a case study in a riverside community in

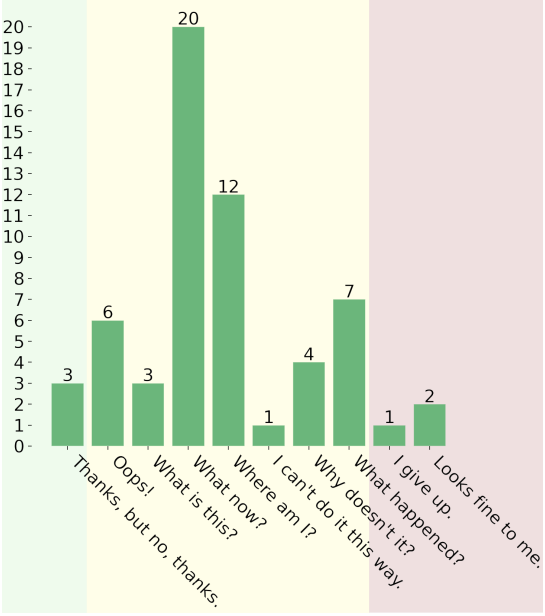

Figure 4. Number of communicability ruptures in the first prototype

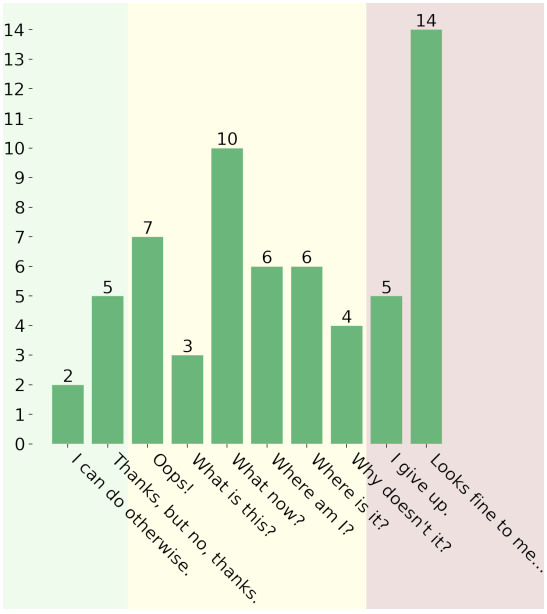

Figure 5. Number of communicability ruptures in the second prototype

the Legal Amazon and a case study in a northeast city of Pará. The CEM, based on Semiotic Engineering, was used in two case studies. The data extracted from these case studies is structured on emergent users' social, financial, and digital aspects. The information gathered in the studies was used to build design considerations, solve interaction barriers, and validate the interfaces developed in the prototypes.

This section present a summary of principal results obtained in both case studies, more details for each case study is presented by Teran [2022]. These summary results highlight the datas collected with emergent users and used like base for development of design and evaluation considerations, personas and, consequently, the Inclue Platform.

5.1 A Case Study with Riverside Community

The first case study involved 12 riverside people, nine women and three men, from a community in the legal Amazon. The participants aged between 26 and 34 studied high school partially (1) or completely (3), while participants aged between 35 and 41 did not complete high school (1) or concluded it (3). Four participants aged between 50 and 74 did not have fundamental schools (elementary and middle school), being the public with more educational barriers.

It was identified that most of the participants worked with the resources provided by the region (6), such as natural resource extraction (4) and gastronomic tourism (2), or were retired (3). All the participants have or had access to a bank account to receive their pensions or aid provided by the public authorities before or during the COVID-19 pandemic.

The static signs were difficult to understand for people aged 50 and over. It was observed that the signs related to educational activities were complex for people with incomplete fundamental school. Three participants with incomplete fundamental school didn't get the meaning of the help sign (Figure 6) because they didn't know it (Figure 7).

Sixty-one communicability rupture tags were generated (Figure 4), and two were removed after filtering the generalizations of the resources to be analyzed. The riverside people's barrier lay in interpreting the actions that could be made on the prototype. For example, it was challenging to perform the actions of the buttons by pressing them instead of touching them. They also sought help to understand which interfaces they could use for their tasks, where they would randomly tap on texts, progress bars, or data entry field icons.

Figure 6. Help Sign

Figure 7. Meaning of Help Sign

5.2 A Case Study in a Northeast City of Pará

The second case study involved 14 residents, 11 women and three men, from the northeast city of Pará. Eight participants were between 42 and 57 years old. Five participants still need to finish fundamental school, and five have finished it. Some reported attending high school partially (3) or completely (1).

Their jobs were day laborers (3), housewives (3), bricklayers (1), farmers (1), hairdressers (1), clothing saleswomen (1), chefs (1), painters (1), and not self-employed (3). Eight of the 14 participants accessed banking services via mobile phone, and six accessed banking services via branches, lottery shops, or with the support of trusted people.

The results also highlight that participants find static signs in educational contexts challenging to understand. For example, the participants indicated several concepts (Figure 9) on the help sign (Figure 8), such as "Help", "Create", "Voice Control", "Random Key" or "Don't know".

Figure 8. Help Sign [Icons8, 2022]

Figure 9. Meaning of Help Sign

Sixty-three communicability rupture tags were generated (Figure 5), and one was removed because it was out of scope

according to the resources analyzed. Although understanding the data validators initially presented some challenges, the metalinguistic signs provided by voice assistants and illustrations supported the participants in carrying out their tasks. As participants progressed through the tasks requested during data collection, they began to use the validators as a support resource for their interactions with the prototype.

5.3 Comparison of Case Studies

By observing the data from the case studies, it was possible to infer correlations and differences between the availability and the possibility of access to financial and digital services provided to riverside people and residents of a city in the interior of the state of Pará, as well as the socio-digital characteristics of these people. Below, we will present some of these correlations that served as a basis for constructing theoretical and practical solutions to include emerging users.

Most participants engaged in independent professional activities, with variable incomes influenced by seasonal or natural factors. Digital technologies can support emerging users when weather or off-seasons affect their family's income. In this context, interactive systems become interesting by allowing registrations and consultations on financial aid through applications or platforms available on the Internet.

The socioeconomic data of the participants highlights that socio-digital barriers tend to increase with the age of emergent users. For example, younger participants had greater access to formal education and felt more confident using digital technologies but faced more challenges related to internet access infrastructure. Older participants faced more significant barriers to accessing formal education, had more difficulties using digital technologies, struggled with internet access infrastructure, and have reduced mobility conditions, such as low vision. The complexity of barriers emerging users face is also aggravated by age and the absence of educational, financial, and digital incentives provided by public and private authorities throughout their lives.

In analyzing the static signs provided to emergent users, it was observed in the study with riverside dwellers that abstract or educational context signs were difficult to interpret for participants with low digital or educational literacy. The signs were adapted to reflect real-world characteristics during the second case study, which facilitated participants' understanding. However, signs related to educational contexts remained challenging to understand. This evidence supported the hypothesis that illustrations, e.g. dynamic and static signs, should be more closely aligned with the everyday contexts of emergent users to enhance their understanding of interfaces and interactions with digital systems.

In the first case study, participants had difficulty performing actions on the prototype or understanding the tasks needed to interact with the instant payment service. However, in the second case study, these difficulties were corrected through instructions given by a voice assistant or animated illustrations, which informed the user of the action or task that the user needed to do on the prototype. In the two case studies, participants performed their instant payment tasks through forms divided into steps and adapted by 5W2H[6]. The majority indicated the organization of forms divided into steps can support carrying out their interactions with the prototype. Therefore, the results found in the case studies were converted into design and evaluation considerations that should strengthen the inclusion of emerging users in interactive systems.

6 Proposed Solutions

This section presents two contributions: a designing and evaluating considerations set (section 6.1) for emergent users inclusion, and a platform to support designers and developers in the accessible real-time payment systems construction (section 6.2).

6.1 Considerations for Real-Time Payment Systems and Emergent Users

The theoretical solution produced in this research provides a set of design and evaluation considerations that software designers and developers can use as a conceptual basis while building real-time payment systems accessible to emergent users. The study embraces design and evaluation considerations in the context of financial applications. Thus, two frontiers are principles for the solution produced: (i) the evolution of design recommendations presented in the literature for the inclusion of emergent users and (ii) the generation of new design and evaluation considerations aimed at accessibility in real-time payment systems for emergent users.

After conducting the case studies with riverside people and residents of a northeast city of the state of Pará, a set of 29 design considerations for real-time payment systems for emergent users was generated [Teran and Mota, 2024]. The considerations were grouped on five categories of interactive system interfaces: data input, data output, navigation, privacy and security, and finally, support. However, the study made by Melo *et al*. [2024] highlighted that some considerations had an interpretation bias, which affected their application in the evaluation of inclusive payment systems for emergent users. Therefore, the design considerations and categories were refined better to suit the evaluation of accessible real-time payment systems.

Thus, a new refinement cycle was made based on the contributions obtained in the study of Melo *et al*. [2024] so that the considerations could be included for the design and evaluation of inclusive real-time payment systems for emergent users. Three HCI researchers conducted this redefinition: a master's student, a doctoral student, and a professor in computer science. Table 1 presents the 33 final design and evaluation considerations classified into four categories: data input, output, visual, and audio.

It is pertinent to mention that the final set of recommendations was achieved through a mixed-method approach, which was developed and refined through various studies utilizing diverse methodological approaches, including interviews, usability tests, inspections, and focus groups.

[6] 5W2H: a tool that helps in carrying out tasks through the questions what, why, where, when, who, how, and how much.

Table 1. Design and Evaluation Considerations Summary

Interface Categories	Design and Evaluate Considerations	Design Considerations [Teran and Mota, 2024]	Evaluate Considerations [Melo *et al*., 2024]	Literature base
Data Inputs and Visual	IV-1. Adapt the mask of a data field to your input	DC-1	CI-1	
	IV-2. Display the keyboard corresponding to the data input	DC-2	CI-2	
	IV-3. Use the keyboard confirmation button to proceed with a task	DC-18	CI-3	
	IV-4. Provide an on and off button for voice assistant support	DC-17	CV-1	Thies; Srivastava *et al*.; Capra *et al*.; Gupta *et al*.
	IV-5. When carrying out form-filling tasks, display only one task at a time on the screen	DC-19	CI-12	Thies; Srivastava *et al*.
	IV-6. After the first access instructions, provide a button to create Pix key	DC-22	CI-15	Central Bank of Brazil
	IV-7. Automatically copy the validation code sent to the smartphone	DC-26	CI-16	Srivastava *et al*.
	IV-8. Instructions should be brief and highlight keywords in specific actions	DC-8	CI-7	Srivastava *et al*.; Capra *et al*.
Data Inputs e Audio	IA-9. Activate the voice command via buttons or by pronouncing activation keywords	DC-16	CV-2	Thies
	IA-10. Provide voice feedback to indicate the keyboard buttons pressed by users	DC-3	CA-2	Srivastava *et al*.; Capra *et al*.
	IA-11. Strengthen user authentication via voice command, with non-sensitive personal data	DC-24	CV-3	Randhawa *et al*.
	IA-12. Provide voice alerts for downtime	DC-27	CV-4	Srivastava *et al*.; Capra *et al*.
Data Outputs e Visual	OV-13. Display a list of the Pix keys created	DC-4	CI-4	
	OV-14. Once you've finished creating a Pix key, add a "Receive via Pix" button to the screen	DC-4	CI-5	
	OV-15. Present icons that are easy to understand	DC-7	CVis-1	
	OV-16. Present animated illustrations that are easy for the user to understand	DC-6	CVis-1	Srivastava *et al*.; Capra *et al*.
	OV-17. Show proof that simulates the physical document	DC-10	CI-6	Srivastava *et al*.; Capra *et al*.
	OV-18. Provide titles and subtitles with large fonts, few characters, and highlighted keywords throughout the application	DC-12	CI-7	Srivastava *et al*.; Capra *et al*.
	OV-19. Provide a graph that makes it easy to see the balance when sending or receiving a Pix	DC-9	CI-8	Srivastava *et al*.
	OV-20. Show a list of favourite users' Pix keys	DC-5	CI-9	Modesto and Ferreira
	OV-21. Enable the user to favorite the recipient's Pix key in the process of paying with Pix	DC-5	CI-10	
	OV-22. Provide the option to edit the data entered before completing the task	DC-20	CI-13	
	OV-23. Define clear orders on forms to minimise errors	DC-23	CI-11	
	OV-24. Show visual effects when the screen changes	DC-15	CVis-2	
	OV-25. Avoid back buttons on task completion screens	DC-21	CI-14	
	OV-26. The voice assistant should ask if the user is in a secure environment before providing personal information	DC-25	CV-3	Randhawa *et al*.
Data Outputs and Audio	OA-27. Customize the app notification sound with a voice assistant	DC-11	CA-1	Srivastava *et al*.; Capra *et al*.
	OA-28. Provide voice feedback to indicate alerts or errors about the data entered by users	DC-13	CA-3	Randhawa *et al*.; Capra *et al*.
	OA-29. Show audio effects when the screen changes	DC-15	CA-4	
	OA-30. Provide an audio description of data previously entered by users	DC-14	CA-3	
	OA-31. When you press on an element, trigger the audio description to display its name	DC-29	CA-5	
Data Inputs, Data Outputs, and Visual	IOV-32. Help the user with a virtual agent	DC-27	CI-17	Srivastava *et al*.; Capra *et al*.
Data Inputs, Data Outputs, Visual and Áudio	IOVA-33. Use voice assistants and animations to help users with their tasks	DC-28	CVis-3	Tulaskar; Capra *et al*.

The design and evaluation considerations are based on the interaction characteristics of emerging users to improve your access to interactive systems, in which banking applications for making transfers in real-time stand out. During the analysis of this solution, the researchers realized that IV-6, OV-13, OV-14, OV-17, OV-18, OV-19, OV-20, and OV-21 are specific considerations to real-time payment systems, and the others can be applied to general interactive systems.

When comparing design and evaluation considerations to WCAG standards, only the OV-18 design evaluation consideration has a direct relationship. Unrelated design and evaluation considerations IV-3, IV-4, IV-7, IA-9, IA-10, IA-11, OV-15, OV-16, OV-24, OV-25, OV- 26, OV-27, OV-29, OV-30, OV-31 and IOVA-33. Table 2 presents the design and evaluation considerations related to WCAG.

The considerations serve as a theoretical solution to support software designers and developers, as their applicability can strengthen the understanding of the design and evaluation of an accessible payment system. They have the potential to minimize the research time and cognitive load of the professionals involved in interactive system development while keeping or increasing their access and communication.

Table 2. Comparison of design and evaluation considerations with WCAG 2.1 and 2.2

Design and evaluation considerations	WCAG 2.1 and 2.2
IV-1	1.3.5 and 3.3.2
IV-2	1.3.5 and 3.3.2
IV-5	3.3.7
IV-8	3.3.2
IA-12	2.2.6
OV-18	2.4.2, 2.4.6 and 2.4.10
OV-22	3.3.6
OV-23	2.4.3
OV-28	3.3.1
IOV-32	3.3.5

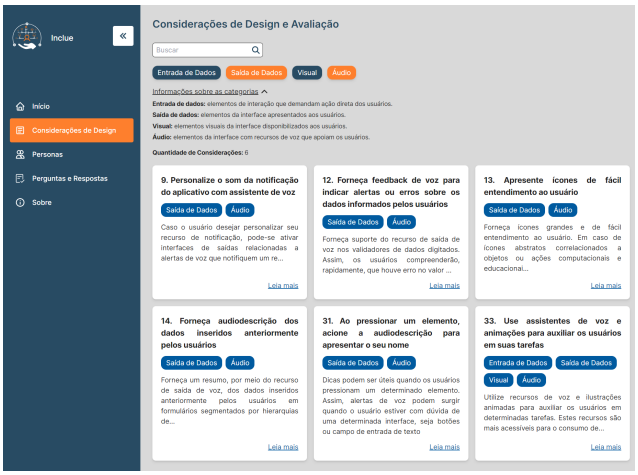

Figure 10. Section "Design and Evaluation Considerations"

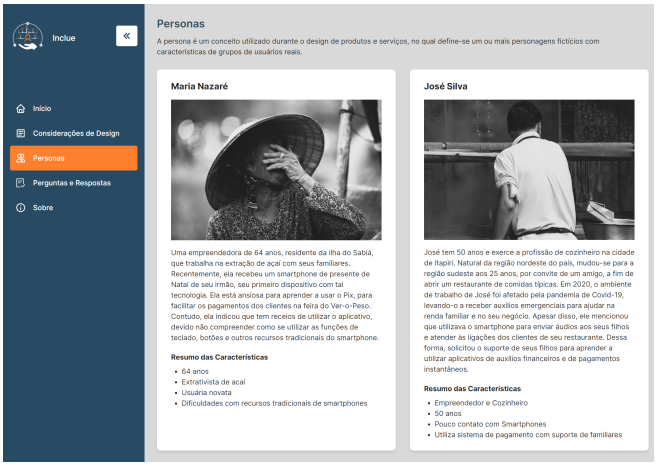

Figure 11. Section "Personas"

6.2 The Inclue Platform

The platform has been named Inclue, which is an acronym for **I**nclue, Guide (in Portuguese "**N**ortear"), **C**onnect, and **L**egitimize emergent users (in Portuguese "**U**suários **E**mergentes"). Inclue aims to support designers and developers in adopting inclusive design practices for emergent users.

The justifications for each definition of this acronym are presented below:

- **Inclue**: Include emergent users in interactive systems;
- **Guide**: Guiding designers and developers on the characteristics of user interaction;
- **Connect**: Connecting real-time payment systems as a financial management alternative for emergent users;
- **Legitimize**: Legitimizing emergent users as protagonists of digital services and sustainable development.

The platform was designed to have five sections. The first section, called **"Start"**, introduces the platform objective and presents the logo and a brief description of the available content, guiding the user in navigation.

The second section called **"Design Considerations"**, presented in Figure 10, contains the reference guide on implementing accessibility features to emergent users. The guide is structured in textual cards with recommendations that can be filtered by category ("Data Input", "Data Output", "Audio" and "Visual") or searched by a textual entry. Each consideration can also present more information by selecting the option "Read more" to read a complete description, find literature references, and implementation examples.

The third section called **"Personas"**, highlighted in Figure 11, presents cards with text and images consolidating characteristics of hypothetical emergent users. Its structure consists of six cards, each with a fictitious name, description, illustrative photo, and the main characteristics of an emergent user.

The fourth section called **"Questions and Answers"**, was designed as a configurable set of questions and answers about the content presented in the previous sections in the form of a *quiz*. The user should be able to choose how many questions and subjects (*Design Considerations* and *Personas*) the quiz should cover. After configuring, the platform allows the user to answer the questions and get the percentage of correct answers at the end.

Finally, the fifth section, **"About"** presents the web application's complementary documents and the research team involved. The platform's source code is available on GitHub, and an operating version can also be accessed[7] without any restriction (Platform link available at the footnote of this page).

It is hoped that the content of the Inclue Platform will be used in the routine of software development professionals. Therefore, this tool can ease the cognitive burden on professionals and reduce the time spent on searching for materials to support inclusive software development. In addition, the platform can be used to teach inclusive design and raise awareness about emergent users accessibility among software designers and developers.

7 Viability Study of Inclue Plataform

The viability study was carried out using a questionnaire made available on Google Forms. In this context, 11 professionals (coded P1 to P11) responsible for software development, including one visually impaired person, participated. These participants answered questions about their professional experience and knowledge of accessibility (section 7.1), as well as questions about their interactions with the Inclue Platform (section 7.2).

7.1 General Information and Knowledge about Accessibility

About the sector in which the participants are employed, six individuals work in the private sector, while five are employed in the public sector. In response to a multiple-choice question, participants indicated their areas of work as follows: finance (9), education (2), and IT industries (1).

Through a multiple-choice question, the professionals indicated their professional activities (Figure 12). The majority work as systems analysts (5), designers (3), front-end developers (3) and HCI researchers (3). Other positions men-

[7] `https://inclue.vercel.app/`

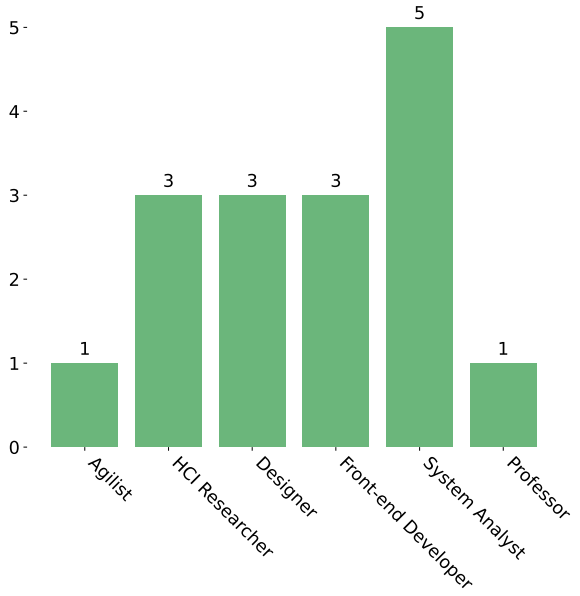

Figure 12. Professionals quantity

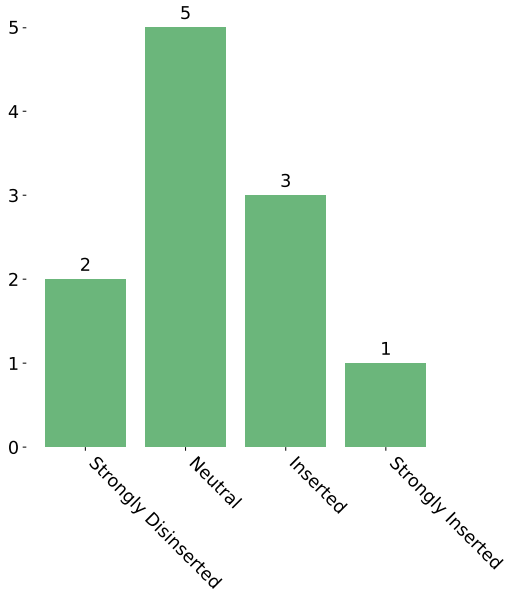

Figure 13. Inserted in accessibility

tioned were agilist (1) and professor (1). Ten professionals have carried out these activities for over three years, and one for two years. The professionals indicated, on a Likert scale, their insertion in the development of accessible software (Figure 13). Two respondents were strongly not inserted, five stated they were weakly inserted, three were inserted, and one was strongly inserted in developing accessible software. When observing the responses, it is possible to realize that accessibility is not a quality criterion emphasized in the software developed by the participants, since more than half of the respondents indicated they are strongly or weakly inserted from the construction of accessible software.

About the emergent users' accessibility of the interactive systems developed by these professionals, seven participants indicated they had worked on developing interactive systems that included emergent users. This result demonstrates that professionals consider emergent users' social characteristics when designing digital services. P1 reported that "*Yes, the projects we develop as a financial institution have these people in the target audience*.", P3 pointed out that "*Yes, we have already adapted the bank's app (name of bank) to the accessibility guidelines, taking into account letters, voice, e.g.*", P8 reported "*I care about this audience, in all my proposed solutions.*" and P11 pointed out "*I am working on two projects for a young low-income audience (shantytown)*".

They were asked whether these professionals work with the inclusion of audiences other than emergent users. Five participants work with accessibility for people with visual impairments. Among the reports, P2 indicated "*Only in portals for public organizations, including mandatory functionalities such as increased font, high contrast, and keyboard navigation shortcuts*.", P4 highlighted "*I am currently developing systems with accessibility for visually impaired people in mind*", and P9 pointed out "*We have already developed activities aimed mainly at contrast control for applications*".

Six professionals indicated that their team or organization discusses the accessibility of their interactive systems. The discussions focus on various stages of the development process for these systems, including resources that may be developed or tested, as well as their potential users. Similarly, P3 pointed out that "*When creating the screen or flow, the increase in screens, colors, and others, is taken into account*", P4 indicated that "*For all the functionalities we are going to develop, we send the prototype to a team responsible for accessibility, and they build the 'accessibility map' which we implement and then validate with them*.", P8 reported that "[...] *we always think about how to include people with disabilities*." and P10 indicated that ' *'We have an accessibility team, where a visual/non-visual duo works with each squad. We also use the support of a research team to validate our customer journeys*".

The remaining five participants indicated that discussions about software accessibility in teams are absent or optional as long as some regulatory body requests them. Thus, P2 said "*No, it probably happens in other areas, but not among my team*.", P7 pointed out "*I currently work on an internal project used only by some employees of a digital bank and, unfortunately, accessibility is not on the agenda of the demands that come to me*.", P9 said "*The discussion takes place but not as a priority*," and, finally, P6 emphasized that "*More or less, if it's a central bank requirement, yes*!". P6 demonstrates the importance of regulatory actions, like the user experience manuals [Central Bank of Brazil, 2022c] and brand usage guidelines [Central Bank of Brazil, 2022a], on the part of control authorities to promote the quality of access to the software developed, given that this can prevent software from being created without considering the population's characteristics.

Only four professionals reported using processes, methods, tools, or guides as supporting artifacts while developing accessible software. They mentioned one or more tools as technical resources for software accessibility, including the WCAG guideline (2), the Google Lighthouse tool (2), and A11y (1).

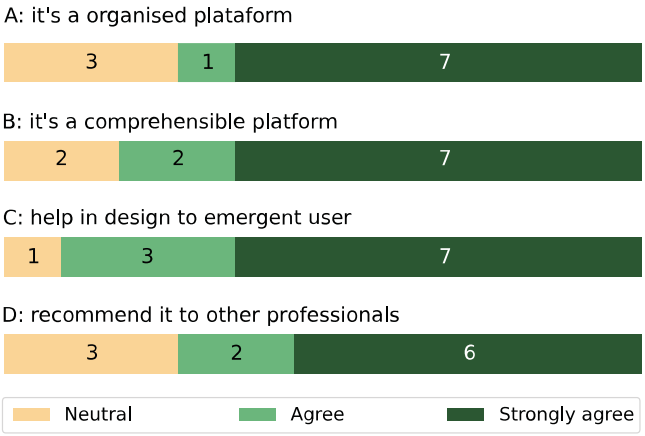

Figure 14. Platform general viability

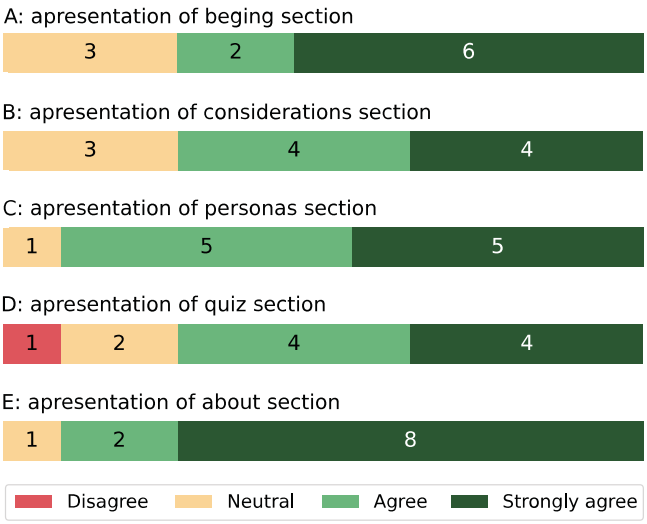

Figure 15. Platform sections viability

7.2 Inclue Platform Interaction

Participants were asked a series of questions to evaluate the viability of their interactions with the Inclue Platform. The first question (Figure 14, item A) was related to the degree of organization of the platform's sections (start; design and evaluation considerations; personas; questions and answers; and about). Consequently, 7 participants indicated that the platform was very organized, 1 stated that it was organized, and three highlighted that it was reasonably organized.

Among the recommendations for improvements to the organization, P9 pointed out that the platform should have a subscription function so that professionals can receive notifications at intervals reminding them how to implement accessibility features. In addition, P10 pointed out that the icons were confusing, and that titles would help identify the functionalities. Another point noted by P10 was that the title "questions and answers" directed his understanding to a FAQ resource related to the use of the Inclue Platform.

Next, we asked how easy it was to understand the content presented (Figure 14, item B), whether it was text, images, videos, or audio. The answers were divided into three categories: slightly understandable, understandable, and very understandable. The highest concentration was given to very understandable, with seven responses. Next, two participants indicated that the platform is reasonably understandable, and two stated it is understandable.

Two professionals recommended improvements for understanding the information on the platform. P2 highlighted the necessity of adding captions to images to improve understanding, especially in the design and evaluation considerations, while P10 emphasized that it is necessary to reduce the amount of text on the platform for better clarity. The professionals also reported whether the Inclue Platform could help them with design and evaluation tasks for emergent users (Figure 14, item C). The majority (7) indicated that the platform could help them a lot, three stated that it could help, and one reported that it could help reasonably.

The professionals said how much they would recommend the Inclue Platform to other professionals (Figure 14, item D). The answers varied between would recommend a lot (6), would recommend reasonably (3), and would recommend (2). Therefore, the highest concentration of responses (8) was that the platform could be shared with other professionals related to accessible development.

They were also asked about each section of the platform (Figure 15). About the "Start" section (Figure 15, item A), 6 participants indicated that it was very well presented, three reported that it was reasonably given, and two said it was well presented.P1 recommended improving the presentation of the platform's technical contributions, stating, "*The start screen should better explain HOW the platform contributes to the described objective.*", P9 indicated that the start screen should present an image corresponding to each item showing the platform's objective and P10 noted that it should contain minimal textual content.

Item B of Figure 15 presents the results of the functionalities and content questions in the design and evaluation considerations section. The professionals were mostly divided between 'very well organized' (4) and 'well organized' (4). Three professionals indicated that the section was reasonably organized.

Three professionals pointed to improvements in the design and evaluation considerations section. P2 pointed out the need to revise the titles and descriptions of the considerations to make them clearer and more straightforward for professionals. P4 pointed out the need to emphasize the information in the design and evaluation considerations categories since he had yet to observe this feature's availability. P10 pointed out that the filter options must be better provided.

Item C of Figure 15 presents the degree of presentation of the Personas section. Five participants indicated that the Personas section was very well presented, and five participants stated that it was well presented. Only one participant, however, reported that the section was reasonably organized. Among the recommendations for improvement, P7 pointed out that the images of the personas were too large, distracting from the text that describes each persona. P10 said there was too much text, and, meanwhile, P11 said there should be more information, such as what the persona feels or says.

Concerning the questions and answers section (Figure 15, item D), the results were mainly divided between very well

presented (4) and well presented (4). Two professionals indicated that the questions and answers section was reasonably well presented, although one participant indicated that it was not well presented.

The professionals presented some improvements for the questions and answers section. P1 indicated that "*Some questions deserve more than one answer or the answers are incomplete*." and P2 pointed out "*I believe that images would be better*."These recommendations were to add media and alternatives that help answer the questions about the personas and design and evaluation considerations. P10 also emphasized that the section's name should be changed to something that represents a test of the platform's content.

Concerning the about section (Figure 15, item E), the majority of professionals indicated that it was very well organized (8) or well organized (2). Only one professional suggested that the platform was reasonably organized. Among the recommendations, participants indicated that complementary materials should be presented at the top of the page, the section title should be improved, and a link to the professional LinkedIn profile should be added to facilitate communication with companies that may request support in using the tool.

To finalize, we asked about the positive and negative points of the Inclue Platform that deserve to be highlighted for their viability. Four professionals highlighted negative points, and three indicated positive ones. The positive points were related to the ease of accessing a guide for building inclusive systems by directing a professional to the accessibility of the resources developed and the comprehensiveness of the theme addressed, which strengthens possible system users. The negative points were related to improving the examples of implementations and functionalities made available for interaction, as in the case of selecting categories, as well as making them more collaborative and with less text.

8 Discussion

The results obtained in this research raise lessons that corroborate the understanding of the digital barriers faced by emergent users (subsection 8.1) and how tools to support inclusive development can help build interactive systems that are more accessible to these people (subsection 8.2).

8.1 Case Studies with Emergent Users and Literature Comparison

The following paragraphs compare the related works with the case studies findings (riverside population and Northeast city cited in Section 5).

From the data analysis obtained in two case studies, we noticed similar effects in the interactions of participants and the results of research presented in the literature. Modesto and Ferreira [2013] indicated that people with low literacy levels need help analyzing and expressing their interactions with search engines due to a lack of previous experience with this resource. This demonstrates that the volunteers in the case studies experienced difficulties interacting with the prototypes' interfaces, primarily due to their lack of familiarity with Pix concepts.

Modesto and Ferreira [2013] also indicated that people with low literacy tend to avoid long texts, which complicates their ability to interpret results. In both case studies, this finding was validated when participants indicated in post-test surveys that texts containing fewer than 50 characters were easier to understand and read.

Medhi *et al*. [2007] highlight that audio resources strengthen the understanding of people with low literacy levels about a given usage scenario. Consequently, eight of the 14 participants in the second case study stated that the prototype's voice assistant significantly improved their understanding of the real-time payment system features. The evidence obtained in two case study through voice assistants demonstrates that this resource can be crucial for emergent users, enabling them to perform tasks independently.

About the static sign analyses, Matthews *et al*. [2017] conducted a study in India on people with low literacy levels and their interactions with digital wallets. They found that abstract icons are difficult for these users to understand. When comparing the two case studies, we found that participants in the first study had difficulty interpreting the static signs. In contrast, in the second case study, participants found it easier to interpret static signs that presented real contexts of specific objects and usage scenarios. However, another complexity of interpretation emerged in the second case study when participants faced challenges in indicating static signs related to linguistic, mathematical, and computational systems contexts.

In conclusion, it is noted that the case study participants are at various stages of interaction [Devanuj and Joshi, 2013]: unexposed, novice, rote learner, fluent, and competent. The data indicates that the stages of experiences vary according to age, in parallel with socio-digital and environmental barriers. These are related to the autonomy of the use of financial systems. In both case studies, the more the age range decreased, the more confident and independent the participants became in accessing the prototypes. Consequently, the more the age group grew, the more users expressed doubts and recipes for using the prototypes. This fact was the exception for a participant; he was 50 years old and worked as an administrative assistant, and daily cell phone or computer use was not recommended.

8.2 Accessibility Knowledge and Inclue Platform Viability

The majority of professionals (7) indicated that they were reasonably involved (5) or entirely distanced (2) from the development of accessible software. It shows that there are few discussions about their tasks to address the accessibility of the resources they develop. It may be due to a lack of contact with the target audience, conversations with work teams, or awareness of the issue through organizational initiatives.

Seven professionals indicated that they seek to develop systems for emergent users. It describes that these professionals have been thinking about and designing resources catering to the characteristics of older people, people with low literacy levels, and those far from urban areas. This kind of awareness of accessibility on the part of software develop-

ment professionals is in line with international actions, such as the 2030 [ONU, 2015] agenda, for the social, digital, and financial inclusion of diverse people.

Digital inclusion must be encouraged in teams and organizations that develop software. According to six professionals, accessibility is not a priority discussed in their environments, given that it is rarely addressed in their team. It may be a priority for other teams, or should only be considered if control institutions require it.

Few professionals are familiar with tools for designing and developing accessible resources. Only four professionals know Google Lighthouse, A11y, and WCAG. These theoretical and practical tools are encouraged in the development environment so that professionals can implement accessible resources more efficiently and at a lower cost.

Most professionals (10) indicated that the Inclue Platform could help them design and evaluate accessible resources for emergent users. This can maximize the learning and insertion of these users' characteristics into development systems, with a lower cognitive load for professionals. Eight professionals also indicated that they would recommend the Inclue Platform to other professionals. It shows that it can be publicized among their contacts to stimulate awareness and use of this practical tool for developing accessible software in the industry.

Professionals made some recommendations for the Inclue Platform. These reports evidence a need to improve the content presented, such as the images, the purpose of the platform, the description of the persona cards, and the design and evaluation considerations. It indicated that the Inclue Platform will become more comprehensible.

9 Threats to Validity

Only some studies were selected for the systematic mapping of the literature. It would be interesting to increase the number of scientific repositories studied in computer science. In relation to the state-of-the-art survey on digital accessibility for emergent users and inclusive design recommendations, the studies retrieved were not analyzed systematically.

Only one reviewer conducted the SIM [de Souza and Leitão, 2009]. Consequently, the number of evaluators may affect the thoroughness of the analysis of the identified gaps. The case study data was collected at the participants' homes, the application of the CEM indicates that external interactions with the environment, conducted by the participants, can influence the analysis of the information by generating noise in the data collected. The ideal scenario is to follow the recommendations presented in Barbosa *et al*. [2021], in which participants interact with the system or proposal in a specific environment that avoids diverting their attention.

The research includes considerations for voice command and biometrics, which were identified based on participants' reports. It is important to note that the prototypes developed did not include voice input or biometrics; although, voice output features were implemented through the voice assistant.

Another complex issue is that the case studies should also have been conducted in banking environments. Although the case studies included potential mobile banking customers, the studies were not yet conducted in financial institutions.

The Inclue platform was not validated using techniques such as, e.g., heuristic evaluation techniques or the SIM for usability and communicability. Additionally, a study should also be conducted on the platform's accessibility, strengthening the ease of access to this tool by software development professionals with disabilities.

The viability of the Inclue Platform was assessed through an online questionnaire distributed to 11 software development professionals. It is important to note that no screen recordings were made during the interaction or interviews with these participants. These techniques could have provided valuable insights for identifying potential improvements to the platform. Moreover, the limited number of volunteers for the study resulted in a low response rate, which may affect the comprehensiveness of the findings.

10 Final Considerations

This article presents a set of studies to improve the accessibility of real-time payment systems for emergent users. Through it, a systematic mapping of accessible software development was carried out; a questionnaire was applied to software developers to find out about the practical scenario of building accessible systems; a survey of the literature on recommendations and studies on accessibility for emergent users; an inspection of a proposal for a real-time payment system from a partner bank in the research; a case study with Amazon riverside peoples; and a case study with residents of a northeast city located in the state of the Pará.

The results showed that most participants reached their income independently, based on seasonal periods and nature. Regarding digital services, it was noted that the participants predominantly use instant messaging apps and social networks to communicate with friends and family. The findings indicate the importance of income acquisition initiatives and that emergent users are wary of using financial services to avoid security breaches and use the support of trusted people when necessary.

Based on the data extraction from the two case studies and the results obtained from the analysis of communicability breakdowns, 29 design considerations for real-time payment systems were generated. These considerations were refined based on a practical inspection study of 5 banking applications, which resulted in 33 design and evaluation considerations for real-time payment systems and emerging users.

With the literature and case study recommendations available, the Inclue Platform was built. This platform is a tool that aims to support software designers and developers in teaching, raising awareness, and building inclusive real-time payment systems for emerging users.

The Inclue Platform was evaluated using an online questionnaire applied to 11 software development professionals. The results show that the Inclue Platform helps include emergent users, and professionals tend to recommend it to other software designers and developers.

In future work, we intend to carry out new studies aimed at emergent users to enhance further these people's social, financial, and digital inclusion. This research could then be

applied to various traditional services mediated by computational systems, such as education or entertainment.

The first case study noted the need to bring more computer research to riverside regions and other traditional communities. These initiatives strengthen the social and digital inclusion of traditional peoples in the Amazon.

According to the second case study, voice command is a resource that can strengthen the interaction of emergent users. It is interesting to build and evaluate new experiences with unconventional digital tools that can enhance the work environment of self-employed professionals who are emergent users.

In this research, it was observed that low-income people could face barriers to accessing interactive systems. Thus, some research can be carried out to investigate "**digital aporophobia**", in Portuguese "Aporofobia Digital", which is a term constructed from analyzing case studies and which highlights the lack of access faced by people on low incomes to digital services. The problem generates the inaccessibility of interactive systems, built without considering the social conditions of low-income people, which must be overcome to include these emerging users in digital services.

Another research that could be conducted is a long-term exploratory search into the working culture of emerging users. It should provide a new look at work experiences and how they can be implemented in computer systems, generating more digital empowerment and profit for these people.

Finally, more in-depth studies could be developed on the Inclue Platform to improve its content and interaction quality. This approach allows research to be applied to strengthen accessibility, usability, and communicability through inspections carried out by HCI researchers, interviews with designers or software developers, and accessibility tests with people with disabilities.

Declarations

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Authors' Contributions

LT contributed to the methodology, building and reviewing the content, surveying the state-of-the-art, conducting the case studies, data analysis, conceptual design, and tool development. GM contributes to the methodology, data analysis, construction of conceptual and practical tools. IM contributed to the state-of-the-art survey and content review. RS contributes to the methodology and tool development. TR contributed to the content review. And MM contributed to the methodology, content review, and research guidance.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The materials used to conduct this research are available at the link `https://bit.ly/open-science-eu-rtps`, strengthening consultation and use for open science and knowledge sharing.

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