






Beyond Detection: A Framework for Transforming Accessibility Evaluations into Implementable Fixes


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Abstract: Ensuring accessibility in government-managed digital platforms is essential for inclusive public services. However, accessibility evaluations often fail to produce actionable outcomes, creating a gap between assessment and implementation. This study presents a structured accessibility framework designed to bridge that gap by converting evaluation findings into implementable fixes. The framework integrates automated and manual assessments, maps each identified barrier to a user-centered justification, and generates structured action points that clearly assign responsibilities to development and design teams. The framework was tested through a pilot application on PNLD Formação (a Brazilian government platform developed as part of the public policy "Programa Nacional do Livro e do Material Didático" – PNLD, or National Textbook Program) and empirically validated on PNLD Avaliação (another governmental platform supporting the pedagogic evaluation phase of the same policy). Additionally, a user survey conducted during the validation phase revealed not only critical usability challenges on one of the platforms but also misconceptions about accessibility and disability among system users. These findings highlight the need for both technical remediation and cultural awareness initiatives. This study contributes a replicable methodology for integrating accessibility evaluation into digital governance, fostering long-term accessibility improvements in large-scale platforms.

Keywords: Accessibility, Government Digital Platforms, Actionable Accessibility Fixes, Inclusive Design, Accessibility Evaluation Framework

1 Introduction

Accessibility is a fundamental principle of inclusive design in interactive systems, ensuring that digital platforms accommodate diverse abilities and needs. Studies highlight that accessibility barriers can be mitigated through assistive technology and inclusive design strategies in educational environments [Poker *et al.*, 2012; Gilbert, 2019]. The World Health Organization (WHO) estimates that over 1.3 billion people globally live with some form of disability, representing approximately 16% of the population [World Health Organization, 2023]. Accessibility, therefore, is not only a technical requirement but also a social responsibility, impacting individuals' access to education, employment, and essential services [de Oliveira *et al.*, 2024].

Government-managed educational platforms play a crucial role in ensuring equitable access to educational resources on a national scale. However, these kinds of systems frequently encounter significant accessibility challenges, including difficulties in navigation for keyboard users and inadequate screen reader support. Addressing these barriers requires systematic evaluation processes that identify critical issues and propose actionable solutions.

While advancements in accessibility standards, such as the Web Content Accessibility Guidelines (WCAG) [World Wide Web Consortium (W3C), 2024], provide valuable benchmarks, their practical application often remains inconsistent. Studies have shown that accessibility improvements are frequently deprioritized due to the absence of clear, actionable guidance for developers [Södergård, 2024], underscoring the need for tools that not only evaluate platforms but also translate findings into concrete actions that design and development teams can implement effectively.

This paper introduces an accessibility evaluation framework aimed at simplifying the evaluation process while fostering inclusivity in large-scale government platforms. The framework combines manual expertise with automated assessment tools to generate prioritized, actionable insights. These insights are tailored to the needs of design and development teams. To test the framework's feasibility, we applied it on PNLD Formação ¹ and PNLD Avaliação ² platforms' accessibility evaluation, generating action points for the development and design teams.

¹<https://pnld-formacao.mec.gov.br/>

²<https://pnld-avaliacao.mec.gov.br/>

Our research contributions are:

- A hybrid accessibility evaluation framework using a methodology that integrates manual and automated approaches.
- Two case studies demonstrating the framework's application and impact on government-managed educational platforms at a national scale.
- Practical insights into improving accessibility practices across similar large-scale and dynamic systems.

The framework closes the gap between diagnostic assessments and implementation by systematically translating each detected barrier into a clear, justified, and actionable task for design and development teams. This approach ensures that accessibility improvements are not only technically sound but also feasible, contextualized, and aligned with team workflows.

The remainder of this paper is structured as follows: section two reviews background and related work, identifying gaps in current accessibility evaluation methods. Sections three and four describe the research methodology and the framework. Section five details the case studies and evaluation results. Section six discusses the implications of the findings, while section seven concludes with directions for future research.

2 Background and Related Works

Government-managed educational platforms present unique challenges due to their large-scale deployment, dynamic contexts, regulatory constraints, and diverse user base [Silva *et al.*, 2024]. These platforms may accommodate millions of users while ensuring compliance with national education policies and accessibility standards. Managing accessibility in such systems requires a structured approach that balances technical feasibility, regulatory requirements, and user-centered design principles [Silva *et al.*, 2024]. Besides, the need for structured approaches in accessibility evaluation aligns with contemporary guidelines for digital inclusion [Guimarães, 2020], emphasizing the integration of inclusive design principles into public services [Gilbert, 2019].

2.1 Regulatory Framework and Accessibility Policies in Brazil

Brazil has developed multiple regulatory guidelines for digital accessibility in government platforms. The **Modelo de Acessibilidade em Governo Eletrônico (eMAG)** was created to standardize accessibility practices in digital services managed by the government. It is based on WCAG principles but was last updated in 2014, making it outdated compared to current accessibility requirements [EMAG, 2014]. The lack of recent updates has posed challenges for government platforms in maintaining compliance with evolving digital accessibility needs. To address this gap, Brazil introduced the **Modelo de Acessibilidade Digital Brasileiro**, which provides updated recommendations for ensuring accessibility across government websites

[Government of Brazil, 2023]. This model emphasizes user-centered design, ensuring that digital platforms remain inclusive and effective for all users, including those with disabilities. However, enforcement and adoption inconsistencies persist, leading to varied levels of accessibility implementation.

2.2 Challenges in Government Educational Platforms

A major challenge in government platforms is requirement volatility, as policies and educational guidelines frequently change due to political and administrative decisions [Silva *et al.*, 2024]. This volatility affects platform design, leading to continuous modifications that can introduce new accessibility barriers if not correctly managed. Studies indicate that platforms with high requirement volatility often struggle with maintaining consistent accessibility features [Brajnik, 2008].

Another challenge is the complexity of integrating multiple stakeholders, including government agencies, software development teams, and accessibility experts. Coordination between these entities is often fragmented, leading to delays in implementing accessibility improvements [Silva *et al.*, 2024].

Besides these challenges, there is the legacy system integration. Some government educational platforms are built on outdated infrastructure, making it difficult to implement modern accessibility features. Retrofitting these platforms for compliance with contemporary accessibility standards requires significant technical and financial resources [Lazar *et al.*, 2017].

2.3 Existing Approaches to Accessibility Evaluation

The evaluation of accessibility in government-managed educational platforms generally employs automated testing tools, manual expert reviews, or a combination of both. Automated tools such as WCAG compliance checkers efficiently detect structural issues but fail to capture user experience challenges, such as intuitive navigation and compatibility with assistive technologies [Mateus *et al.*, 2021; Hong *et al.*, 2008]. Manual evaluations by accessibility experts help identify these limitations and refine usability improvements [Mateus *et al.*, 2021; Hong *et al.*, 2008].

The GranDIHC-BR 2012 report has long identified digital accessibility and inclusion as core research challenges for the HCI community in Brazil, underscoring the urgency of building tools and methodologies that bridge socio-technical gaps in public digital platforms [Baranauskas *et al.*, 2014].

Several of the newest Brazilian HCI research agendas reinforce this perspective. The GranDIHC-BR 2025–2035 reports identify socio-technical and inclusive design approaches as critical for national development. Our framework aligns explicitly with GC4 (Sociocultural Aspects), GC6 (AI in HCI: Ethics, Diversity, and Inclusion), and GC7 (Interaction with Emerging Technologies), as they call for integrated, adaptive, and ethical accessibility

methodologies [Neris *et al.*, 2024; Duarte *et al.*, 2024; Zaina *et al.*, 2024].

Hybrid approaches that integrate automated and manual assessments have been proposed to address these limitations. Medina *et al.* [2024] provides a recent review of more than 100 accessibility evaluation studies, demonstrating the growing consensus around mixed-methods approaches and identifying persistent gaps in transforming evaluation into practice. Studies suggest that incorporating user testing with individuals with disabilities alongside automated accessibility testing can provide a more comprehensive assessment [Mateus *et al.*, 2021; Hong *et al.*, 2008]. However, there remains a gap in the process that translates evaluation findings into concrete design and development improvements.

Research has shown that accessibility efforts are most effective when development teams have clear guidelines that translate compliance requirements into actionable development tasks [Campoverde-Molina *et al.*, 2020]. Additionally, accessibility evaluation in large-scale government platforms requires a hybrid approach that combines automated testing with manual assessments [Hong *et al.*, 2008].

2.4 Gaps in Current Research

Despite existing standards like WCAG, research highlights gaps in ensuring that accessibility evaluation leads to practical design changes [Campoverde-Molina *et al.*, 2020]. Studies emphasize the need for structured frameworks that not only assess accessibility but also integrate recommendations directly into development workflows [Pichiliani and Pizzolato, 2021; Brajnik, 2008].

Additionally, government-managed educational platforms face challenges related to requirement volatility, stakeholder coordination, dynamic environments, and practical accessibility evaluation. Addressing these issues requires comprehensive frameworks that bridge the gap between compliance assessments and actionable implementation strategies, ensuring sustainable accessibility improvements at scale.

3 Methodology

This section describes the methodology used in this research, from the framework's development to its empirical validation in two real contexts, as described in Figure 1.

We adopted a Design Science Research (DSR) approach [Hevner *et al.*, 2004] to develop and validate a framework for accessibility evaluation in complex and dynamic software using the context of government-managed educational projects for its empirical validation. We began with a literature review to analyze various accessibility evaluation methods, ensuring a comprehensive understanding of existing approaches and their practical implications [Lazar *et al.*, 2015]. Based on this analysis, we defined transparent and replicable action points that serve as the foundation for the framework's structure. To empirically validate our approach, we conducted a pilot study within

the PNLD Formação project, applying the proposed methodology in an authentic government-managed educational setting. Additionally, we collected expert feedback from accessibility specialists, enabling an iterative refinement process to enhance the framework's robustness and applicability. This DSR-driven methodology ensures that the final framework is empirically grounded, practically applicable, and aligned with accessibility best practices [Brajnik, 2008].

The development of the proposed accessibility framework followed a structured method that aimed to systematically identify, categorize, and address accessibility barriers in large-scale government platforms. This methodology was designed to ensure that accessibility evaluations were not only compliant with regulations but also actionable and implementable in real-world settings, particularly in highly dynamic and complex systems with high requirement volatility [Silva *et al.*, 2024].

Unlike generic audits that stop at problem identification, our methodology ensures that each barrier leads to a clearly defined fix, with responsibility assigned (development or design), a rationale based on user impact, and replicable formatting for broader applicability. The action points are formulated to fit within agile cycles and design sprints, enhancing their real-world viability and adoption. This structured pipeline—from evaluation to implementation—serves as the central mechanism by which the framework ensures its effectiveness in dynamic, high-scale environments.

The methodological approach was divided into six key steps: (1) Accessibility Evaluation and Mapping of practical examples for each rationale, (2) Creation and Classification of Action Points, (3) Expert Validation, (4) Pilot Application in PNLD Formação government educational platform, (5) Framework Refinement and Final Deliverables, and (6) Empirical Validation in PNLD Avaliação platform. These steps ensured that the evaluation process was adaptable, scalable, and capable of generating structured improvements in digital accessibility.

3.1 Accessibility Evaluation and Mapping of practical examples for each rationale

The first step consisted of a detailed analysis of various accessibility evaluation methods, integrating both automated and manual approaches. Automated tools played a crucial role in identifying compliance issues with WCAG 2.2 standards, particularly in areas such as:

- Color contrast deficiencies that could impact users with visual impairments;
- Incorrect use of semantic HTML elements, affecting screen reader users;
- Missing Accessible Rich Internet Applications (ARIA) attributes required for assistive technologies;
- Keyboard navigation inconsistencies preventing full interaction without a mouse.

Despite the efficiency of automated evaluations, they alone are insufficient for capturing deeper user experience

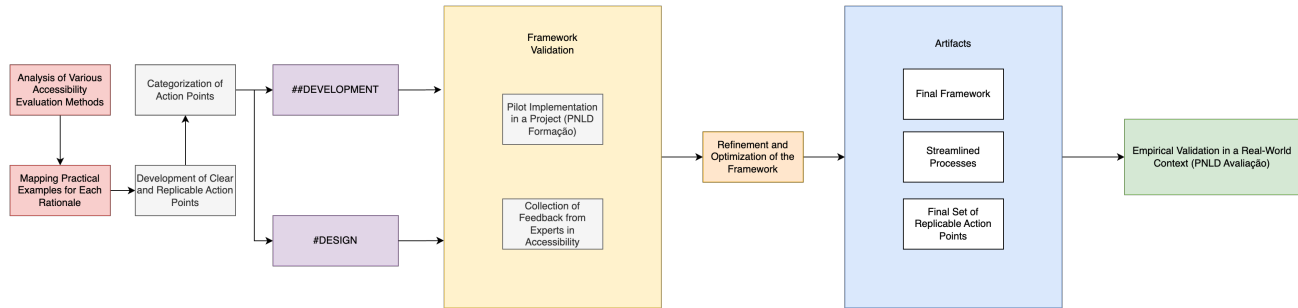


Figure 1. Framework Design methodology: Step-by-step process for the development, refinement, and validation of the proposed accessibility framework. The workflow begins with the analysis of various accessibility evaluation methods and the mapping of practical examples to support each rationale. This leads to the development and categorization of clear, replicable action points, split into development and design tracks. The framework is then validated through a pilot implementation in PNLD Formação and expert feedback, followed by refinement. The final deliverables include the complete framework, streamlined processes, and a repository of replicable action points. The process concludes with empirical validation in a real-world context via the PNLD Avaliação platform.

barriers. Thus, a complementary manual assessment was conducted, in which experts in accessibility and user experience performed the assessment. These tests provided insights into interaction complexities, cognitive accessibility concerns, and navigation difficulties that automated tools could not detect.

To further strengthen the evaluation process, an additional step of mapping practical examples for rationale was introduced, consisting of linking each identified accessibility barrier to practical user impact scenarios, ensuring that all identified issues had a well-documented rationale. The rationale mapping process helped prioritize issues by severity, user impact, and feasibility of remediation, ensuring that the most critical accessibility problems were addressed first.

3.2 Creation and Classification of Action Points

Following the evaluation phase, identified accessibility barriers were converted into structured and replicable Action Points, facilitating their implementation by development and design teams. The goal of this phase was to ensure that accessibility assessments led to concrete, practical improvements rather than remaining as abstract reports. To ensure clear responsibilities and ease of implementation, the Action Points were categorized into two main areas:

- **Development-Oriented Actions:** These addressed technical adjustments that software developers could implement. Examples included ensuring proper ARIA implementation, restructuring HTML for better semantic accuracy, refining keyboard accessibility, and improving compatibility with assistive technologies.
- **Design-Oriented Actions:** These focused on enhancing the user interface and overall usability, ensuring that visual and interactive elements were accessible. Key aspects included improving contrast ratios, adding clear focus indicators, standardizing spacing and typography, and enhancing feedback mechanisms in interactive components.

Each action point was replicable, meaning it could be applied across different systems with similar accessibility

challenges. This structure enabled the development of a standardized accessibility improvement process that could be systematically applied to other governmental digital platforms.

3.3 Expert Validation

Once the action points were established, they were subjected to a validation process by two accessibility specialists. These experts reviewed the methodology, ensuring that the classification of accessibility barriers and their corresponding recommendations were aligned with international best practices in inclusive design, usability heuristics, and assistive technology compatibility.

The validation focused on several key aspects:

- The technical feasibility of each recommendation;
- The expected impact of implementing each action point on end-user accessibility;
- The clarity and specificity of the proposed recommendations;
- The degree to which the recommendations were generalizable to other governmental digital platforms.

This expert validation was crucial to ensuring that the framework was not only theoretically sound but also practical and implementable within the constraints of real-world governmental systems.

3.4 Application in the PNLD Formação platform

Following expert validation, the proposed framework was applied in a real-world case study involving the PNLD Formação platform, a national-scale system used for training educators within the scope of Brazil's National Textbook Program (PNLD). This pilot application served to test the framework's feasibility in a complex government platform, identify practical challenges, and refine its structure based on empirical findings.

The evaluation combined automated and manual methods. Automated testing was conducted using tools such as

Wave Evaluation Tool ³, commonly used for auditing WCAG compliance. These tools helped detect structural accessibility issues, including missing ARIA roles, contrast errors, and improperly labeled components. The manual inspection followed a structured checklist based on WCAG 2.2 guidelines. It was conducted by two professionals: one accessibility consultant with more than five years of experience in inclusive design and one UX specialist with a background in governmental interface evaluation.

In total, the pilot evaluation required approximately 10 hours of combined work: 2 hours for automated scanning and triage, 5 hours for manual analysis and justification mapping, and 3 hours for collaborative synthesis into action points. The automated tools used were employed in their freely available versions, so no financial costs were incurred.

The accessibility issues were mapped to justifications with concrete user impact scenarios and then translated into action points. Action points were then discussed with three members of the platform's internal team (one front-end developer and two UI/UX designers), who confirmed each item's technical feasibility and clarity. This feedback loop helped ensure that recommendations were realistic within the platform's current development cycle.

To illustrate the practical application of the justification mapping process, we present a representative example extracted from the PNLD Formação evaluation, addressing a usability barrier associated with cognitive overload on the knowledge base interface.



Figure 2. Knowledge Base Print Screen from PNLD Formação

During the manual expert inspection, it was observed that the interface displayed an excessive volume of simultaneous information, including nested menu items, large text blocks, and multiple interaction elements, all presented without clear prioritization. This layout challenges users by

demanding sustained focus and increasing the likelihood of disorientation. To mitigate this, the identified issue was converted into a design-oriented action point recommending the implementation of progressive disclosure, as shown in Figure 2. This solution involves reorganizing the interface to reveal only essential information initially, with additional details accessible on demand. The action was justified as a means of reducing cognitive load and improving task orientation, especially for neurodiverse users. The recommendation was assigned to the UX design team and structured in a way that allows adaptation to other modules or platforms where similar information density is present.

3.5 Framework Refinement and Final Deliverables

Based on the practical insights gained from the PNLD Formação implementation, the framework was refined to enhance its efficiency, adaptability, and scalability. The refinements led to the formalization of three key deliverables:

- *Finalized Accessibility Framework* as a comprehensive methodology for evaluating and improving accessibility in large-scale governmental digital platforms.
- *Streamlined Processes* as a structured approach to accessibility assessments that is adaptable to high-complexity systems with volatile requirements.
- *Replicable Action Points Repository* as a catalog of standardized and reusable accessibility improvements applicable across various government-managed digital platforms.

These deliverables represent a systematic and scalable approach to digital accessibility, enabling long-term improvements in usability, compliance, and user experience. The complete set of action points, including detailed justifications, recommended actions, and implementation roles, is available in the supplementary material repository for replication and reuse ⁴.

3.6 Empirical Validation in PNLD Avaliação platform

The final iteration of the framework was applied to the PNLD Avaliação platform, providing empirical validation in a real-world governmental context. This phase aimed to test whether the framework was effective, adaptable, and generalizable beyond a single case study. The validation process consisted of:

- **End-User Feedback Analysis:** Collecting qualitative feedback from users, including individuals with disabilities, to assess their perspectives on the actual accessibility state of the platform.
- **Baseline Accessibility Benchmarking:** Measuring the initial accessibility state of the platform before the framework was applied.

³<https://wave.webaim.org/>

⁴https://osf.io/e82n3/?view_only=11f7d60d60d240d99a779ed0e1bdf6fc

- **Iterative Implementation and Refinement:** Applying the framework and tracking the ongoing evolution of accessibility improvements.

As a real example from this step, we describe an issue concerning the login interface, where several form fields lacked proper <label> elements and ARIA attributes. This issue was initially flagged through automated accessibility tools and subsequently confirmed by manual inspection. From an accessibility standpoint, the absence of semantic labels severely impairs usability for screen reader users, who rely on these attributes to understand the function of each input field. The user impact was classified as high, given that this barrier directly affects the ability to access the platform's core functionalities. Based on this diagnosis, the issue was mapped to an action point requiring the explicit association of each input field with a visible <label> and relevant ARIA descriptors. This development-oriented action was deemed essential for ensuring compatibility with assistive technologies and was assigned to the front-end development team. Because this type of issue is recurrent in digital forms, the action point was also marked as replicable across similar modules in other platforms.

By successfully applying the framework to PNLD Avaliação, its scalability and adaptability to other government platforms were confirmed. The results, detailed in section 5 demonstrated that the framework provided a structured and actionable approach to accessibility improvements, ensuring compliance with national and international regulations while enhancing user experience.

3.7 Ethical Considerations

This study adhered to national and institutional ethical standards for research involving human participants. Two separate ethics approvals were obtained from the Research Ethics Committee (Comitê de Ética em Pesquisa – CEP) of the Federal University of Alagoas. The analysis of user feedback in the PNLD Avaliação platform was conducted under approval number CAAE: 69059623.1.0000.5013, and the procedures related to the PNLD Formação platform were approved under CAAE: 75375623.0.0000.5013.

The data analyzed in this article from PNLD Avaliação originated from two open-ended questions embedded in a broader usability survey conducted for a separate research project. These questions asked users whether they identified as having a disability and how such a condition affected their interaction with the platform. Participation was entirely optional, and users were clearly informed of the voluntary nature of their responses. No personally identifiable information was collected or stored, and all responses were anonymized and analyzed in aggregate form.

Only these two qualitative questions were used in the present study, while the full survey results are reported in other research paper [Silva et al., 2025]. To promote transparency and reproducibility, the research materials—including the survey questions, action point examples, and anonymized feedback data—are openly available in the Open Science Framework repository at: https://osf.io/e82n3/?view_only=11f7d60d60d240d99a779ed0e1bdf6fc.

4 Accessibility Framework Evaluation

The accessibility framework developed in this study provides a structured approach for evaluating and improving the accessibility of large-scale governmental platforms. By integrating manual and automated evaluations, this framework ensures that accessibility barriers are identified, justified, and converted into actionable improvements that can be effectively implemented by development and design teams. This section details the framework's structure, as depicted in Figure 3.

The framework is based on a multi-stage process that integrates accessibility evaluation with structured remediation strategies, ensuring that findings lead to measurable improvements. The key components of the framework are:

- Accessibility evaluation through automated and manual assessments
- Justification of identified issues with user-centered explanations and rationales
- Issues conversion into structured action points classified as development or design issues.
- Implementation of accessibility fixes by development and design teams
- Validation and continuous iteration based on feedback and usability testing

The structured workflow ensures systematic accessibility improvements while maintaining compliance with national and international accessibility standards, including Web Content Accessibility Guidelines (WCAG 2.2), the Brazilian Digital Accessibility Model, and eMAG.

4.1 Accessibility Evaluation

Accessibility issues are identified using a hybrid approach that combines automated testing and manual assessment.

Automated testing involves the use of accessibility auditing tools to detect structural and semantic compliance issues, such as missing alternative text, improper ARIA attributes, insufficient contrast ratios, and mislabeling of form fields.

Manual assessment is conducted by experts performing evaluations and usability tests using personas that rely on assistive technologies. This phase identifies challenges such as navigation difficulties, lack of clear focus indicators, and cognitive overload due to excessive visual elements.

By combining these methods, the evaluation provides a comprehensive view of accessibility gaps, ensuring that issues are not only identified but also contextualized in terms of user impact.

4.2 Justification of Identified Issues

A critical step in the framework is ensuring that each identified issue is mapped to a concrete rationale and

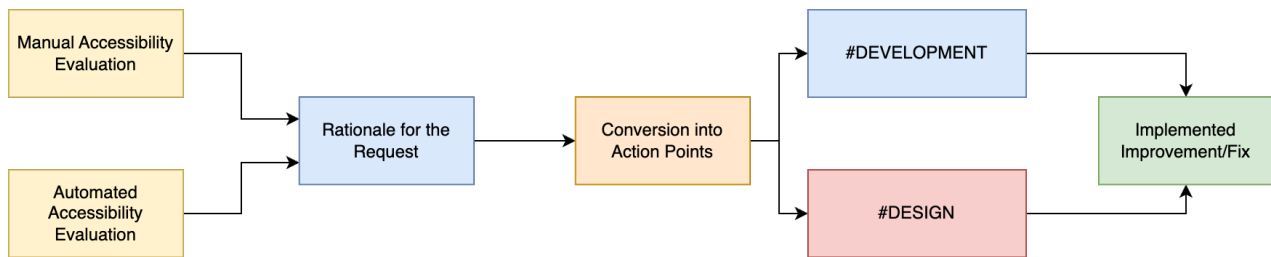


Figure 3. Accessibility framework diagram showing the steps from evaluation to action: beginning with automated and manual accessibility evaluation, followed by rationale for the request, conversion into action points, implementation by design and development teams, and implemented improvement or fix.

justification, together with practical examples. This process is essential for prioritizing remediation efforts and ensuring that development and design teams understand why each improvement is necessary. For example:

- Missing labels for form fields prevent users from relying on screen readers to understand the function of input elements, leading to navigation difficulties.
- Low contrast between text and background reduces readability for users with visual impairments, impacting usability.

Providing a user-centered rationale for each issue helps teams prioritize fixes that have the greatest impact on accessibility.

4.3 Conversion into Action Points

Once accessibility barriers are justified, they are converted into structured, actionable tasks, referred to as action points. These are categorized into two primary domains.

Development-oriented action points require code-level modifications to improve accessibility compliance, such as adding labels to form components, inserting alternative text for images, ensuring correct association of labels with user and password fields, improving tab order and focus indicators, replacing empty buttons and links with meaningful descriptions, and adjusting button sizes and spacing to facilitate touch interactions on mobile devices.

Design-oriented action points focus on visual and interaction-based improvements to enhance usability and readability. Examples include making the platform responsive to different screen sizes, adjusting color combinations to conform to WCAG contrast guidelines, implementing a breadcrumb navigation system, refining typography variations for better content organization, reducing cognitive overload through progressive disclosure, and ensuring that all icons have descriptive text labels.

The structured classification of action points ensures that accessibility issues are not only fixed but also integrated into broader UX and UI design improvements.

4.4 Implementation in Development and Design

After converting accessibility barriers into action points, these tasks are assigned to respective teams based on their classification.

The development team is responsible for addressing issues requiring code-level changes, such as improving form structures, optimizing keyboard navigation, and refining ARIA attributes.

The design team focuses on enhancing the visual hierarchy, refining typography, improving contrast ratios, and adjusting layout structures to accommodate accessibility needs.

By integrating accessibility fixes directly into the product development cycle, the framework ensures that improvements are effectively implemented without disrupting existing workflows.

4.5 Validation and Continuous Iteration

After the implementation of action points, a final validation phase is conducted to measure the effectiveness of applied fixes, with follow-up accessibility audits to verify compliance with accessibility standards; user testing with assistive technology to evaluate improvements in navigation and usability and iteration based on feedback, ensuring continuous refinement of accessibility features. For instance, after applying keyboard navigation improvements, further testing is conducted to ensure that tab order and focus indicators function as intended across all interactive elements. Similarly, after adjusting contrast ratios, users with visual impairments are consulted to confirm enhanced readability.

5 Results

This section presents the results obtained from the pilot application of the accessibility framework on the PNLD Formação platform and the empirical validation conducted on the PNLD Avaliação platform, in which we also analyze user feedback collected through a survey, discussing the misconceptions identified among respondents. The findings demonstrate the framework's effectiveness in identifying and mitigating accessibility barriers, as well as its adaptability to different governmental platforms.

5.1 Pilot Application on PNLD Formação

The first application of the accessibility framework was conducted on the PNLD Formação platform as a pilot study to evaluate its feasibility and effectiveness, refining it to its actual version. The accessibility assessment was performed

using a hybrid methodology that combined automated testing tools and manual evaluations conducted by accessibility experts.

The assessment revealed several accessibility barriers that affected the usability of the platform. Among the most critical issues were:

- **Lack of labels in form elements:** Many input fields lacked proper labels, making it difficult for screen reader users to understand their purpose.
- **Insufficient color contrast:** Several interface components did not comply with WCAG AA contrast guidelines, reducing readability for users with visual impairments.
- **Inadequate keyboard navigation:** Some interactive elements were not reachable using the keyboard, preventing users who rely on keyboard navigation from accessing all functionalities.
- **Absence of ARIA attributes:** Interactive components such as modals and dropdown menus lacked proper ARIA attributes, leading to inconsistencies in screen reader navigation.

Based on these findings, structured action points were developed to address the identified issues. These were categorized into development-oriented and design-oriented tasks. Key improvements included:

- Inserting appropriate <label> elements for form fields to enhance screen reader compatibility.
- Adjusting color contrast settings to meet WCAG AA standards.
- Ensuring all interactive elements were accessible via keyboard navigation.
- Implementing ARIA roles and attributes to improve screen reader interpretation.
- Restructuring the navigation system to enhance usability for users with cognitive disabilities.

These action points were reviewed by members of the development and design teams to ensure their clarity and objectivity. Based on their feedback and the feedback from two other accessibility experts, the framework was refined to its current version.

5.2 Empirical Validation on PNLD Avaliação

Following the success of the pilot study, the framework was applied to PNLD Avaliação for empirical validation. The goal was to assess its effectiveness in another real-world government platform used for evaluating educational materials. Although both platforms — PNLD Formação and PNLD Avaliação — operate within the same domain, specifically the pedagogical evaluation of educational resources under the PNLD public policy, their development teams are distinct. While one platform supports stakeholder training, the other focuses on the evaluation process itself.

The accessibility evaluation identified several usability issues, many of which overlapped with those found in PNLD Formação. Notable barriers are:

- Missing alternative text for images, making visual content inaccessible to screen reader users.
- Inconsistent tab order and lack of focus indicators, creating navigation difficulties.
- Buttons and links without meaningful descriptions confuse users.
- High cognitive load due to excessive information being displayed at once.
- Lack of responsiveness, leading to usability issues on mobile devices.

The framework facilitated the development of structured action points to mitigate these issues. Improvements included:

- Adding alternative text to all images, ensuring full accessibility for visually impaired users.
- Implementing a logical tab order and visible focus indicators to improve keyboard navigation.
- Enhancing button and link descriptions to provide clearer interaction cues.
- Introducing progressive disclosure techniques to reduce cognitive load.
- Making the platform responsive to various screen sizes, improving mobile usability.

The development and design teams can now use the action points to fix the platform's accessibility issues objectively.

These results confirm that the accessibility framework is effective in diagnosing and mitigating barriers in complex government platforms.

5.3 Survey Results and Misconceptions Analysis

A user survey ⁵ was conducted on the PNLD Avaliação study to gather insights into user experiences with accessibility before the framework's application. A total of 251 participants responded, of whom seven provided open-ended feedback regarding accessibility. Among the seven respondents, four identified as having a disability. Users with disabilities reported specific accessibility challenges related to information processing, navigation, and readability. One user with attention-deficit/hyperactivity disorder (ADHD) and repetitive strain injury (RSI) highlighted difficulties with excessive navigation steps required to access tasks, suggesting a reduction in the number of clicks and the addition of a warning system to prevent accidental data loss. Another user, who has high-degree astigmatism, found the font sizes too small, which slowed down reading, recommending larger text for improved accessibility. A third user suggested multi-tab functionality within the system interface to facilitate parallel task execution. In contrast, responses from users without disabilities demonstrated varying perceptions of accessibility. One user acknowledged the general usability difficulties of the platform and strongly criticized its design inconsistencies, attributing them to an apparent lack of UX

⁵The survey conducted in this study received ethics approval from the Research Ethics Committee (CEP) of the Federal University of Alagoas under CAAE: 69059623.1.0000.5013.

expertise in the development process. Another respondent expressed a misconception about cognitive disabilities, implying that individuals with such conditions would not be capable of performing evaluative tasks. A third respondent also exhibited a prejudiced stance, asserting that professionals in educational evaluation roles would inherently not have cognitive disabilities.

These findings underscore not only objective accessibility barriers but also perceptual biases regarding disabilities in professional environments. The feedback highlights the necessity of design optimizations, such as streamlined navigation, enhanced readability, and improved task management, while also demonstrating the importance of awareness and training on inclusive design principles among system users and stakeholders. The results from PNLD Formação and PNLD Avaliação confirm that the proposed accessibility framework is effective in diagnosing, addressing, and mitigating accessibility barriers in governmental digital platforms. The key findings were that:

- The framework successfully integrates automated and manual evaluations to provide a comprehensive accessibility assessment.
- Structured action points ensure that accessibility improvements are clear, actionable, and feasible.
- Empirical validation confirmed that accessibility enhancements lead to tangible usability improvements for diverse user groups.
- Survey responses highlight the importance of addressing misconceptions about accessibility and disability in digital environments.

In the next section, we delve deeper into these findings and their impact, discussing limitations and future work agendas.

6 Discussion

The results of this study confirm the potential effectiveness of the proposed accessibility framework in systematically identifying and addressing accessibility barriers in large-scale governmental platforms. By integrating automated and manual evaluations, the framework ensures a comprehensive assessment of usability challenges while translating findings into structured and actionable recommendations. Compared to existing accessibility research, these results reinforce the importance of combining evaluation methodologies to achieve meaningful accessibility improvements.

The findings align with prior studies that emphasize the limitations of relying solely on automated testing tools for accessibility evaluations [Mateus *et al.*, 2021]. While automated tools efficiently detect compliance technical failures, they fail to capture broader usability issues related to cognitive load, navigation complexity, and assistive technology use. Previous research highlights the necessity of hybrid approaches that combine automated scanning with expert evaluations and user testing [Mateus *et al.*, 2021; Hong *et al.*, 2008]. This study further supports the argument that accessibility audits require a multi-layered approach

to ensure that the barriers affecting users with disabilities are fully addressed. The empirical validation on PNLD Avaliação demonstrated that critical accessibility gaps, such as inconsistent keyboard navigation and cognitive overload, would have gone undetected without manual assessments.

A key contribution of this study is the structured methodology for converting evaluation findings into concrete, actionable improvements, aligning with existing research on accessibility in education, which highlights the transformative role of digital tools in inclusive learning [Corrêa *et al.*, 2021]. Many accessibility evaluations focus on diagnosing compliance failures without providing structured remediation strategies, leading to a gap between evaluation and implementation [Södergård, 2024]. The proposed framework addresses this gap by classifying accessibility issues into development-oriented and design-oriented action points. This structured classification ensures that each recommendation is clearly defined and can be directly implemented by the relevant teams, making accessibility improvements more feasible within existing development cycles. By integrating accessibility fixes into the product development workflow, the framework promotes a proactive approach to accessibility rather than treating it as an isolated compliance effort.

Beyond technical barriers, this study revealed attitudinal biases and misconceptions about disability among system users. The survey responses from PNLD Avaliação highlighted a significant gap in accessibility awareness, particularly regarding cognitive disabilities. Some respondents expressed the belief that individuals with cognitive disabilities would be incapable of performing evaluative tasks, reinforcing exclusionary assumptions that contradict inclusive design principles. These findings align with previous research emphasizing that accessibility challenges extend beyond technical limitations and include broader cultural and organizational factors [Pichiliani and Pizzolato, 2019]. Addressing these misconceptions is essential for fostering an inclusive digital environment, and accessibility initiatives should incorporate training and awareness programs to reduce bias in professional settings.

The results also highlight the specific challenges of implementing accessibility solutions in governmental platforms. Unlike commercial platforms, governmental digital services often face additional constraints related to requirement volatility, legacy infrastructure, and multi-stakeholder coordination [Silva *et al.*, 2024]. These factors create barriers to maintaining consistent accessibility practices, making it critical to adopt structured frameworks that ensure long-term sustainability. The success of the accessibility evaluation framework in PNLD Formação and PNLD Avaliação suggests that governmental institutions must go beyond essential compliance and invest in long-term accessibility governance. Future accessibility policies should integrate structured methodologies like the one proposed in this study, ensuring that digital services are continuously evaluated and improved based on user needs.

The findings of this study also raise important implications for the scalability and adaptability of accessibility frameworks. The structured methodology used in PNLD Avaliação demonstrates that accessibility improvements

can be implemented in a systematic and repeatable manner. By ensuring that accessibility evaluations lead to concrete changes, the framework contributes to a more sustainable approach to digital accessibility in government services. Future research should explore the application of this framework to additional government platforms to assess its generalizability across different digital ecosystems. Additionally, integrating assistive technologies into educational platforms can enhance accessibility in meaningful ways, as emphasized in prior studies [Poker *et al.*, 2012; Guimarães, 2020]. Furthermore, longitudinal studies are needed to evaluate the long-term impact of accessibility interventions and determine how accessibility improvements evolve.

A central contribution of this study lies in how the proposed framework ensures the practical implementation of accessibility improvements. Rather than treating accessibility evaluation as an isolated process, the framework embeds remediation directly into development pipelines through its structured generation of action points. Each barrier is not only identified and justified but also translated into a concrete task that aligns with the workflows of multidisciplinary teams, integrating UX designers, developers, QA testers, and requirements engineers. This tight coupling between assessment and execution is what enables the framework to go beyond theoretical diagnosis and deliver measurable improvements in usability and compliance. The supplemental material ⁶ provides visual documentation of these mappings, as shown in Figure 4, further supporting reproducibility and cross-team communication—two critical elements in accessibility governance at scale.

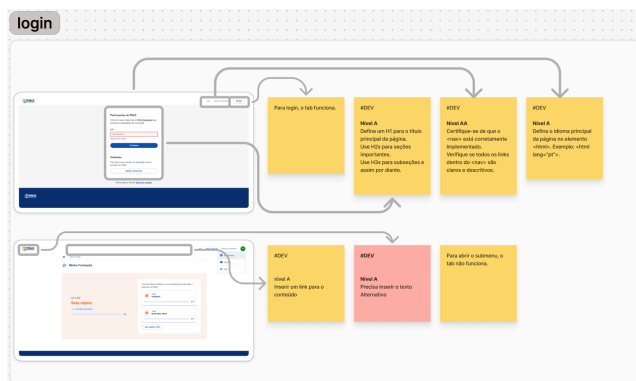


Figure 4. Example of visual mapping from the Accessibility Analysis

This study confirms that a structured, multi-layered approach to accessibility evaluation is feasible for identifying and resolving usability barriers in governmental platforms. The integration of automated and manual assessments ensures comprehensive issue detection, while the structured classification of action points facilitates implementation. By explicitly assigning responsibility and mapping user impact, the framework helps teams address barriers efficiently and pragmatically. However, the findings also emphasize the need for broader cultural changes, particularly in addressing misconceptions about

disability and fostering accessibility awareness. By embedding accessibility considerations into both technical workflows and organizational policies, governmental platforms can move beyond compliance-driven accessibility efforts toward a more sustainable, user-centered approach.

7 Final Remarks

This study presented a structured accessibility framework designed to evaluate and enhance the accessibility of large-scale governmental platforms. Through a hybrid evaluation methodology integrating automated and manual assessments, the framework ensures a comprehensive identification of accessibility barriers while providing clear, actionable recommendations. The pilot application on PNLD Formação and the empirical validation on PNLD Avaliação demonstrated the framework's effectiveness in diagnosing accessibility issues, implementing improvements, and fostering a user-centered approach to inclusive design.

Regarding this research limitation, the accessibility evaluations were conducted on two specific governmental platforms, which, while representative of large-scale digital services, may not fully encompass the diversity of accessibility challenges present in other systems. Future research should expand the framework's application to a broader range of government-managed platforms, testing its adaptability across different digital ecosystems. Second, while the framework integrates user feedback, the sample size of participants with disabilities in the survey was relatively small. A more significant, more diverse sample would provide deeper insights into how accessibility improvements impact different disability groups, particularly in cognitive and neurological conditions. Third, the study primarily focused on short-term accessibility improvements and did not track long-term adoption and maintenance of accessibility fixes. Future research should conduct longitudinal studies to assess the sustainability of implemented changes over time.

Another important limitation is the reliance on expert evaluations for manual assessments. While this approach ensures thorough and reliable findings, it does not fully capture the lived experiences of end-users with disabilities. Future work will seek to incorporate participatory design methodologies, where users with disabilities are directly involved in co-designing accessibility solutions. Additionally, while the framework provides structured action points, it does not yet integrate automated tracking mechanisms for monitoring the progress of accessibility improvements. Future implementations of the framework will explore the development of accessibility dashboards and real-time monitoring tools to track compliance and usability metrics dynamically.

Also, while the study focused on public-sector digital services, private-sector platforms could also benefit from structured accessibility assessment methodologies. Furthermore, incorporating artificial intelligence-driven tools to enhance automated accessibility testing could improve the efficiency of evaluations while reducing

⁶https://osf.io/e82n3/?view_only=11f7d60d60d240d99a779ed0e1bdf6fc

reliance on manual assessments. Machine learning models trained on accessibility best practices could assist in detecting complex usability barriers that are currently difficult to identify through rule-based automated tools.

Another key consideration for future research is the role of accessibility training and education. The survey results revealed that misconceptions about cognitive disabilities persist among system users. Addressing these misconceptions requires more than technical fixes; it necessitates organizational shifts toward greater accessibility awareness. Future work could explore the impact of integrating accessibility training programs for development teams, UX designers, and decision-makers within governmental institutions. Educating stakeholders and end-users on inclusive design principles could lead to more proactive accessibility improvements rather than reactive compliance-driven efforts.

This research provided a replicable and structured methodology for addressing accessibility in governmental platforms, emphasizing practical implementation strategies. By focusing on translating evaluation findings into implementable fixes and integrating them into development workflows, the framework demonstrates that a systematic approach to accessibility evaluation leads to tangible improvements, benefiting users with disabilities while enhancing overall usability. Future research should continue refining these practices to ensure their effectiveness across diverse organizational contexts.

Beyond the specific context of educational systems, this framework offers potential for adaptation in other types of interactive systems that serve the public. Platforms in domains such as eHealth, civic engagement, and other digital government services often face similar challenges in ensuring accessibility across large-scale, dynamic environments. The structured methodology proposed here—particularly its emphasis on actionable guidance and team-aligned implementation—can be customized to support inclusive design efforts in these domains. As accessibility becomes an increasingly critical pillar of digital equity, adaptable frameworks like this one will be essential for fostering inclusive public infrastructure.

Declarations

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Authors' Contributions

This study was developed through the collaboration of multiple authors, each contributing to different aspects of the research. Paula Palomino led the conceptualization, investigation, and methodology, as well as data curation, formal analysis, and the writing of the original draft. André Araújo and Thiago Cordeiro provided supervision and project administration while also contributing to the review and editing process. Alenilton Silva contributed to the investigation and data curation. Rafael Araújo, Diego Dermeval, and Rodrigo Lisboa were involved in reviewing and editing the manuscript. Grace Lis participated in data curation, formal analysis, validation, and manuscript revision. Sofia Simanke contributed to the validation, ensuring the accuracy and reliability of the findings. Each author played a critical role in refining the study, ensuring methodological rigor, and enhancing the clarity and impact of the final manuscript.

Competing interests

The authors declare that they have no competing interests..

Availability of data and materials

The supplementary materials include full accessibility evaluation tables for the PNLD Formação and PNLD Avaliação platforms (in both Portuguese and English), survey instruments, and the complete set of anonymized participant responses. All materials are available in the project's OSF repository: https://osf.io/e82n3/?view_only=11f7d60d60d240d99a779ed0e1bdf6fc. Last access: 02 July 2025.

Citation Diversity Statement

We recognize the importance of citation diversity and have intentionally included a wide range of perspectives in accessibility research. Our references encompass foundational studies, recent developments, and work from diverse geographic, institutional, and disciplinary contexts, with a particular focus on contributions from underrepresented groups.

References

- Baranauskas, M. C. C., De Souza, C. S., and Pereira, R. (2014). I grandihc-br — grandes desafios de pesquisa em interação humano-computador no brasil. *Relatório Técnico. Comissão Especial de Interação Humano-Computador (CEIHC) da Sociedade Brasileira de Computação (SBC)*, pages 27–30.
- Brajnik, G. (2008). Beyond conformance: The role of accessibility evaluation methods. In Hartmann, S., Zhou, X., and Kirchberg, M., editors, *Web Information Systems Engineering – WISE 2008 Workshops*, pages 63–80, Berlin, Heidelberg. Springer Berlin Heidelberg.
- Campoverde-Molina, M., Luján-Mora, S., and García, L. V. (2020). Empirical studies on web accessibility of educational websites: A systematic literature review. *IEEE Access*, 8:91676–91700. DOI: <https://doi.org/10.1109/ACCESS.2020.2994288>.
- Corrêa, L., Taniguti, G., and Ferreira, K. (2021). Tecnologias digitais aplicadas à educação inclusiva: Fortalecendo o

- desenho universal para a aprendizagem. *Instituto Rodrigo Mendes*.
- de Oliveira, L. C., Amaral, M. A., Bim, S. A., Valença, G., Almeida, L. D. A., Salgado, L. C. d. C., Gasparini, I., and da Silva, C. B. R. (2024). Grandihc-br 2025-2035-gc3: Plurality and decoloniality in hci. In *Proceedings of the XXIII Brazilian Symposium on Human Factors in Computing Systems*, pages 1–19. DOI: <https://doi.org/10.1145/3702038.3702056>.
- Duarte, E. F., Palomino, P. T., Pontual Falcão, T., Porto, G. L. P. M. B., Portela, C. d. S., Ribeiro, D. F., Nascimento, A., Costa Aguiar, Y. P., Souza, M., Moutin Segoria Gasparotto, A., et al. (2024). Grandihc-br 2025-2035-gc6: Implications of artificial intelligence in hci: A discussion on paradigms ethics and diversity equity and inclusion. In *Proceedings of the XXIII Brazilian Symposium on Human Factors in Computing Systems*, pages 1–19. DOI: <https://doi.org/10.1145/3702038.370205>.
- EMAG (2014). Modelo de acessibilidade em governo eletrônico (emag) - versão 3.1. <https://emag.governoeletronico.gov.br/>, Accessed: 02 July 2025.
- Gilbert, R. M. (2019). *Inclusive design for a digital world: Designing with accessibility in mind*. Apress.
- Government of Brazil (2023). Modelo de acessibilidade digital brasileiro. <https://www.gov.br/governodigital/pt-br/acessibilidade-e-usuario/acessibilidade-digital/>, Accessed: 02 July 2025.
- Guimarães, M. J. S. (2020). *Design inclusivo na contemporaneidade: diretrizes ao desenvolvimento de materiais didáticos acessíveis a crianças cegas e com baixa visão*. Tese de doutorado, Universidade Estadual Paulista (Unesp). <https://repositorio.unesp.br/handle/11449/231160>, Accessed: 02 July 2025.
- Hevner, A. R., March, S. T., Park, J., and Ram, S. (2004). Design science in information systems research. *MIS quarterly*, pages 75–105.
- Hong, S., Katerattanakul, P., and Joo, S. J. (2008). Evaluating government website accessibility: A comparative study. *International Journal of Information Technology & Decision Making*, 7(03):491–515. DOI: <https://doi.org/10.1142/S0219622008003058>.
- Lazar, J., Feng, J. H., and Hochheiser, H. (2017). *Research Methods in Human-Computer Interaction*. Morgan Kaufmann, Cambridge, MA, 2nd edition.
- Lazar, J., Goldstein, D. F., and Taylor, A. (2015). *Ensuring digital accessibility through process and policy*. Morgan kaufmann.
- Mateus, D. A., Silva, C. A., De Oliveira, A. F., Costa, H., and Freire, A. P. (2021). A systematic mapping of accessibility problems encountered on websites and mobile apps: A comparison between automated tests, manual inspections and user evaluations. *Journal on Interactive Systems*, 12(1):145–171. DOI: <https://doi.org/10.5753/jis.2021.1778>.
- Medina, L., Lopez, G., Díaz-Oreiro, I., and Brenes, J. A. (2024). Current practices in accessibility evaluation: A literature review of over 100 studies. In *2024 IEEE VII Congreso Internacional en Inteligencia Ambiental, Ingeniería de Software y Salud Electrónica y Móvil (AmITIC)*, pages 1–8. IEEE.
- Neris, V. P., Rosa, J. C. S., Maciel, C., Pereira, V. C., Galvão, V. F., and Arruda, I. L. (2024). Grandihc-br 2025-2035-gc4: Sociocultural aspects in human-computer interaction. In *Proceedings of the XXIII Brazilian Symposium on Human Factors in Computing Systems*, pages 1–14. DOI: <https://doi.org/10.1145/3702038.3702057>.
- Pichiliani, T. C. P. B. and Pizzolato, E. B. (2019). A survey on the awareness of brazilian web development community about cognitive accessibility. In *Proceedings of the 18th Brazilian Symposium on Human Factors in Computing Systems*, pages 1–11. DOI: <https://doi.org/10.1145/3357155.3358448>.
- Pichiliani, T. C. P. B. and Pizzolato, E. B. (2021). Cognitive disabilities and web accessibility: a survey into the brazilian web development community. *Journal on Interactive Systems*, 12(1):308–327. DOI: <https://doi.org/10.5753/jis.2021.982>.
- Poker, R. B., Navega, M. T., and Petitto, S. (2012). *Acessibilidade na escola inclusiva: tecnologias, recursos e o atendimento educacional especializado*. Editora Oficina Universitária.
- Silva, A., Araújo, A., Palomino, P., Araújo, R., and Dermeval, D. (2025). Adaptive usability in public sector platforms: A mixed-method evaluation and design approach. Manuscript under review.
- Silva, A. S., Araújo, A., Palomino, P., Araújo, R., and Dermeval, D. (2024). Mastering requirements volatility: Strategies for dynamic environments and multiple stakeholders in government software projects. *IEEE Access*, 12:183060–183077. DOI: <https://doi.org/10.1109/ACCESS.2024.3510056>.
- Södergård, H. (2024). Enhancing web accessibility: Developer perspectives and practical solutions. Master's thesis, Aalto University, Espoo, Finland. <https://aaltodoc.aalto.fi/items/0912a5e0-12b3-469e-af22-8819861b7afc/full>, Accessed: 02 July 2025.
- World Health Organization (2023). Disability and health. <https://www.who.int/news-room/fact-sheets/detail/disability-and-health>, Accessed: 02 July 2025.
- World Wide Web Consortium (W3C) (2024). Web content accessibility guidelines (wcag) 2.2. <https://www.w3.org/TR/WCAG22/>, Accessed: 02 July 2025.
- Zaina, L., Prates, R. O., Delabrida Silva, S. E., Choma, J., Valentim, N. M. C., Frigo, L. B., and Bicho, A. D. L. (2024). Grandihc-br 2025-2035-gc7: Interaction with emerging technologies: An ecosystem integrating humans technologies and contexts. In *Proceedings of the XXIII Brazilian Symposium on Human Factors in Computing Systems*, pages 1–21. DOI: <https://doi.org/10.1145/3702038.3702060>.