

A STUDY ON ACCESSIBILITY ASPECTS OF SOFTWARE DEVELOPMENT IN BRAZIL

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ABSTRACT: Software accessibility promotes the inclusion of people who would otherwise not be able to access such computer systems. This access has become increasingly important as we progressively favor digital alternatives to services such as banking, entertainment consumption, study, work, and shopping. This work objective was to understand the experience of Brazilian software developers regarding accessibility, how it has been implemented in projects they develop in the organizations in which they work, and the challenges involved in doing so. We interviewed 15 Brazilian software developers and then analyzed the interview transcripts from a qualitative perspective. The results indicate that, although developers understand accessibility and recognize its importance, there is a lack of the technical and theoretical knowledge necessary to develop accessible software. They also show that the organizations they work for neglect accessibility due to increased cost and development time.

Keywords: Accessibility, Human-Computer Interaction, Software Development, Software Developer, Software Engineering

1. INTRODUCTION

Several studies have been conducted on the software accessibility area, especially after the popularization of the Internet and the increase of available content in the last two decades. Although accessibility in software development is not directly or exclusively connected to the use of websites and applications on the Internet, it is not possible to disregard its importance when 63% of the world population currently uses the Internet, a growth of more than 1300% over the data from the year 2000 (Group, 2022).

In Brazil, access is mostly through mobile devices, more than twice as much (98.6%) than through computers (46.2%), according to IBGE (Brazilian Institute of Geography and Statistics) data from 2019 (IBGE Indicadores, 2019). This scenario adds complexity to the already popular debate about software accessibility, since these devices alone already offer interaction challenges (Leite et al., 2021)

Accessibility in this scenario promotes the possibility that people with disabilities can, in addition to perceiving, understanding, browsing, and interacting, also contribute to the Web, as defined by the W3C (World Wide Web Consortium) (W3C, 2022). The scope of this accessibility extends to websites and their contents, as well as the tools and technologies that make them available.

The primary audience for whom accessibility is critical includes people with visual, cognitive, neurological, hearing, speech, and physical disabilities, but also benefits people without disabilities with temporary or specific limitations, such as older adults, users of devices with very small screens, very slow internet connection or situational limitations of being unable to use audio or video resources, for example (W3C, 2022). This whole context highlights the importance and growing relevance of accessibility in software, reflected even in the creation of explicit laws and policies for this purpose in several countries, including Brazil (W3C, 2018; Brasileiro, 2019).

Despite all these advances, recent studies show that accessibility is still not considered by developers and people involved in software construction. Showing growth when compared to 2008, but still with very incipient values; data from 2018 indicate that only 35.7% of developers considered accessibility aspects in the development of their projects (Antonelli et al., 2018). Considering only development for mobile devices in Brazil, it is noteworthy that more than half of developers do not use evaluation methods, although only 28% assume they do not employ any accessibility recommendations (Leite et al., 2021).

In addition to the developer's intention or responsibility, the aspects related to the training of all those involved in software development, the dissemination of knowledge on the subject, legislation, norms, and the social and market benefits need to be considered in the debate on this gap (Leite et al., 2021).

Thus, this work objective was to understand the experience of Brazilian software developers regarding accessibility, how it has been implemented in projects they develop in the organizations in which they work, and the challenges in doing so. Moreover, to identify the barriers that may be hindering the creation of more accessible software. For doing so, we designed and conducted an interview with 15 Brazilian software developers. The interviews were recorded and transcribed, and we qualitatively analyzed the data collected to find recurring patterns that could help our understanding of the introduced situation.

This work comprises 6 sections: Section 2 presents the related work; Section 3 presents the research methodology adopted; Section 4 presents the results; Section 5 presents a discussion on the results; Section 6 presents final considerations and future work.

2. RELATED WORK

The subject of how accessibility is perceived and handled by the software sector in Brazil has been extensively addressed in the literature. It is possible to notice an advance in this subject regarding mobile technologies and the diversity of disabilities that can and must be addressed when creating software and making content available.

In previous work, we explored accessibility issues in software development through a systematic literature mapping, a questionnaire with people involved in the software development process, and a mapping of tools used for automated tests for accessibility validation. The developer's lack of knowledge in accessible software development is often deemed one of the primary barriers to the problem of accessibility availability, as we will exemplify in the related work presented in this section. The results found aroused our interest in researching about the experience of the software developers themselves and understand their perspective on the subject.

The first work to consider a significant number of participants in the investigation of accessibility perception by software developers in Brazil had the participation of 613 people from 27 states (Freire et al., 2008). It aimed to identify the main accessibility-related issues in software development and how developers and other people approach them. The results showed that despite being empathetic and recognizing the importance of accessibility for the digital inclusion of people with disabilities, software developers were unaware of the problems related to the development of accessible web applications. Furthermore, they did not know how to evaluate them, as they were unaware of the standards and legislation of the country. Few respondents had training on the subject, which was cited as the primary justification for not meeting accessibility requirements, followed by the fact that it is not a requirement of the organization or the customer, as well as issues of time and cost, among others with less representation. Two recommendations emerged from the results: including accessibility in courses related to web development from high school to undergraduate courses and dealing with accessibility with the necessary seriousness, involving governments, educators, and the whole society to promote awareness.

A second survey on the perception of Brazilian developers, with a significant sample, was conducted in 2018 and collected 404 responses in order to understand the knowledge of Brazilian web developers about accessibility and how they considered this requirement in their projects (Antonelli et al., 2018). The results did not differ a decade after the study cited in the last paragraph (Freire et al.). Just over half of the participants have never developed an accessible website, most do not know how to use automated tools to evaluate accessibility adequacy, and are not familiar with national and international guidelines and standards. Once again, the lack of training is cited as the main difficulty in improving accessibility on the web, followed by the fact that it is not a customer requirement nor a priority of the organization and deadline issues. Focus on another target audience, work overload, cost, and non-applicability of accessibility laws were also mentioned. The authors' suggestions to face the difficulties listed are: awareness actions for the general population, training with an inclusive approach to software development activities, and greater rigor in monitoring compliance with existing laws.

A different perspective is presented in (Rodrigues et al., 2018), research focused on developing a checklist to support developers and experts in web usability and accessibility evaluations for older adults. The checklist - initially suggested - with 51 questions, was based on usability heuristics, accessibility guidelines, and specialized recommendations for older adults. The questions were grouped on five main difficulties encountered by this public on web application use, such as reading and text comprehension, recognizing and accessing

links, navigating, performing specific tasks, and searching and locating information. Another study addressing an area historically little explored in works on accessibility brings a reflection on the concentration of accessibility guides and recommendations for people with visual impairments, citing the WCAG and eMAG as an example and bringing cognitive disabilities to the agenda (Pichiliani & Pizzolato, 2019). Cognitive disabilities are considered in this research as those of cognition, neurological, or learning. There are no references or technical guidelines that consider the different conditions contained in these terminologies. The results showed that most professionals do not consider users with cognitive disabilities in their projects or only partially consider them. For those who consider this audience, the main guideline is the WCAG; for the others, the two main reasons for not considering the audience with cognitive disabilities are the lack of knowledge about the subject and the fact that the organization does not consider this audience as a target of the projects developed.

In the diversification of content found in the most recent works, a study involving 872 participants from all regions of Brazil addressed the issue of accessibility in the context of mobile devices, seeking to understand the perception, knowledge, adoption, motivations, and barriers reported by industry developers (Leite et al., 2021). This study presented important reflections about the responsibility of software developers in the way development projects deal with accessibility. It discussed the importance of the commitment of all people involved in the process and the critical role that organizations play in this context. When people with disabilities are not considered potential users and the organization is not familiar with the legislation, there will be no explicit requirements to make mobile apps accessible. The study's conclusion presents the authors' opinion that when organizations include accessibility in business priorities, it would be possible to overcome the main barriers associated with lack of time and training, and lack of requirements or organizational projects presented by developers to the adoption of accessibility in projects.

Another well-studied aspect is the inclusion of accessibility in the software development process, with three systematic reviews having already been conducted (Freire et al., 2007; Fortes et al., 2010; Paiva et al., 2021). With these studies, works from 1998 to 2019 were covered, considering more than two decades of research. The most recent systematic review shows that the main focus of research on the inclusion of accessibility in the development process is focused on the areas of testing and design, with the indication of a slight increase in the number of papers on the subject (Paiva et al., 2021).

Accessibility from the practitioner's perspective was revisited in a recent study (Bi et al., 2021) with a methodological approach that combined data analysis collected through 15 interviews and a survey, involving people from 26 countries, with 365 answers. The results showed that most developers do not have practical experience working with accessibility, despite the vast majority recognizing its importance. Several interviewees mentioned factors such as the cost-effectiveness of implementing or adapting software to make it accessible. In general, the participants do not perceive the possibility of introducing accessibility as a requirement from the beginning of the development process. The authors also present results on the increase in the industry's demand for qualified professionals in accessibility versus the lack of attention to this subject in colleges and universities, connecting with another result, demonstrating the participants' perception of how much organizations play a critical role in incorporation and enhancement of accessible development.

3. METHODOLOGY

For this research, we designed and conducted an interview with Brazilian software developers. We interviewed 15 volunteers in order to understand more about the Brazilian software developer's relationship with the development of accessible software. The data collected during the interview was analyzed under a qualitative approach, and this section presents the detailed methodology. Figure 1 shows the steps followed in the development of this work. The Ethics Committee of the *Anonymous-Institution* approved this research under the number XXXX.

3.1. Interview Design

We designed a fully-structured interview (DiCicco-Bloom & Crabtree, 2006) that contained 30 questions, 25 general questions we asked every participant, and five specific questions that were asked depending on whether the interviewee had already implemented software with accessibility concerns or not. Participants with previous experience answered 29 questions, and participants with no experience answered 26 questions. The interview was divided into five sections: Personal Information, Organizational Information, Knowledge in Accessibility, Experience with Accessibility, and Opinions on Accessibility. The script contained a combination of open-ended and closed questions in an effort to explore in depth the participants' knowledge and experience on the topic. Table 1 presents the interview questions.

3.2. Participants

To participate in the interview, we recruited software developers who were employed and who possessed or were pursuing an undergraduate degree in the technology field. The recruitment process started at a local company, with contacts through social networks asking about the availability to participate. At each interview, participants were asked if they could suggest new professionals from other companies who could be interviewed. The suggested professionals were then contacted, and the interviews were scheduled.

In total, we interviewed 15 software developers from 13 different organizations who volunteered to participate without any compensation. Only one volunteer who had agreed to participate in the study withdrew his consent during the interview process; when asked questions about the organization for which they worked, they informed us that they had signed an NDA (non-disclosure agreement) and could not answer the questions. As they could not participate, they withdrew their acceptance of the consent form, we ended the interview and discarded all data that had been collected so far, including the audio recording. This paper will refer to the participants as Px , x being the participants' identifier and ranging from 1 to 15 (e.g., $P1$, $P2$, $P3$).

Section	Identifier	Question
Personal Information	Q1	How old are you?
	Q2	Do you have higher education? If yes, in which course?
	Q3	How long since you graduated?
	Q4	How many years of software development experience do you have?
Organizational Information	Q5	Is the organization you work for in the public or private sector?
	Q6	How many years have you worked in this same organization?
	Q7	How big is your organization approximately?
	Q8	Are the projects you develop in your organization concerned with accessibility?
	Q9	Does your organization have an accessibility specialist?
	Q10	Does your organization provide any accessible development training?
Knowledge in Accessibility	Q11	In your own words, can you describe what you understand as accessibility?
	Q12	Do you know any accessibility guidelines (such as the WCAG)?
	Q13	Would you know of the existence of any Brazilian rule or law that focuses on public policies for the development of accessible software products?
	Q14	During your higher education, was accessibility in software at any time discussed, if so, in which class(es)?
	Q15	Do you think your education was enough to fully develop accessible software?
	Q16	Could you describe to me how blind people interact with computing devices like a cell phone or a computer?
	Q17	Could you describe to me how people with motor limitations interact with computing devices like a cell phone or a computer?
Experience with Accessibility	Q18	Does someone in your personal life (relative, friend, or even yourself) have a disability?
	Q19	Does someone in your professional life (who works in the same organization as you) have a disability?
	Q20	What do you think are the biggest challenges to include accessibility in software development?
	Q21	Have you ever developed, at a personal or work level, projects that considered accessibility aspects?
	Q22	Can you give me a brief summary of the projects with accessibility considerations you've worked on?
	Q23	To which accessibility category were they targeted? (Visual, hearing, motor, etc.)
	Q24	What reasons led this project(s) to take into account accessibility concerns?
	Q25	What platform(s) was it(s) directed to?
	Q26	What reasons led this project(s) not to take into account accessibility concerns?
Opinions on Accessibility	Q27	In your opinion, what is the importance of thinking about accessibility in software development?
	Q28	In your experience, what is the current state of accessibility in software? And what is the reason for this state?
	Q29	In the software development process, do you think that accessibility should be taken as a requirement to those who will develop it or should those who develop it consider it an essential step of development?
	Q30	What practical actions do you think could be taken to make more accessible software available?

Table 1: Interview Questions

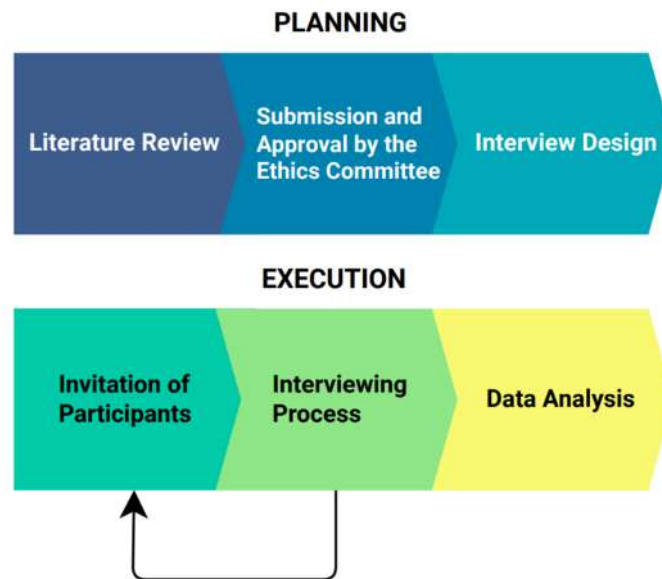


Figure 1: Sequential activities followed in the development of the work.

3.3. Interviewing Procedure and Transcription

At least two days before the interview, each participant received a copy of the informed consent form so that they could understand the terms of their participation and decide, during this period, if they still wanted to partake. The interviews were conducted through a Google Meet call, and before starting the interview, the volunteer digitally signed the consent form. After collecting the signature, the interviewer started recording the audio and followed the interview script. The volunteers did not need to turn on their cameras, and each interview lasted between 15 and 20 minutes.

The interview recordings were transcribed using an online automated text transcription service (Microsoft, 2022), and each interview yielded about three pages of plain text. The text was then reviewed to adjust any transcription errors and tabulated to facilitate data analysis.

3.4. Qualitative Analysis

We analyzed the tabulated data collected from the interviews using Thematic Analysis (Sharp et al., 2019), an inductive qualitative analysis process in which we seek to identify patterns, or themes, considered relevant in the data. Themes emerged from the process of Open Coding, segmenting data into meaningful expressions, and summarizing them in short concepts.

Two rounds of open coding were performed; the first sought to identify the codes, and the second was to eliminate irrelevant codes and group similar codes into just one. Finally, the codes were grouped into themes. At the end of the analysis process, we had a total of 21 codes that were grouped into nine different themes, which we will discuss further in the Results section.

4. RESULTS

We analyzed the collected data under a quantitative approach, and we present our findings in this section. The results were grouped into three primary perspectives: Personal, Educational, and Organizational. From the qualitative analysis, recurring patterns, or themes, emerged, and each perspective will contain a group of themes backed by quantitative data.

The software developers participating in the interview were between 22 and 38 years old, and Figure 2 shows the age distribution. The interviewees were all employed, and only one of the 15 worked in the public sector; all the others worked in the private sector. As for years of experience with software development, the volunteers represented a balanced distribution between novices, intermediates, and experienced, as shown in Figure 3.

Of the 15 interviewees, only four indicated that they have a person with a disability in their personal life, and also, only four indicated that they work with people with disabilities. As for the size of the organizations in which they work, most of them concentrated on small and medium-sized companies, according to the interviewees who were able to estimate their sizes. Figure 4 shows the distribution of the size of the organizations by the number of employees.

4.1. Personal Aspect

This aspect groups the findings related to the individual interviewed, their understanding of accessibility, and their relationship with accessible software development.

4.1.1. Developers Understand Accessibility

Some interview questions sought to better understand developers' knowledge about accessibility and accessible software. All interviewees had a correct general notion of accessibility, describing it as a means of providing equal access and ease of use for anyone. P8 defined accessibility as: “[...] creating means of equity that allow everyone to access the most diverse environments, places, and information.”. P4, as another example, said: “Accessibility (in the development context) is when you make your application easy to be used by all groups of people [...]”.

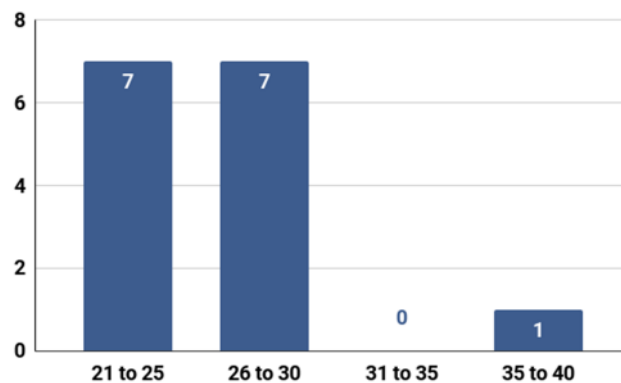


Figure 2: Distribution of participants according to their age.

We also explored whether participants had knowledge of assistive technologies used by people with disabilities to interact with computing devices such as smartphones and computers. We asked them to describe, if they knew, how people with vision impairments and people with a physical or mobility disability interact with these devices. For both questions, more than 80% of respondents (87% for vision impairments and 80% for mobility impairments) were able to answer at least one form of assistive interaction correctly.

For vision impairments, some interviewees described the basic functioning of screen reading software, and some even mentioned the names of tools, such as Android TalkBack and Apple VoiceOver. P6 said: “*I believe it is mainly through audio feedback. Android has a feature called TalkBack that describes everything on the phone screen [...]*” and P15 replied: “*I know some software that reads the screen, they read all the text content available there, such as subtitles, or the text itself [...]*”.

Participants mainly cited eye-tracking, motion detection, and voice assistants for mobility impairments. P9 said: “*Technologies that capture the movement of some part of the body [...]*”, P10 answered: “*[...] If it's a limitation in the lower limbs, I think it doesn't need any accessibility, if it's a motor limitation in the upper limbs, more specifically in the hands, I think it would be more appropriate to go to the side of voice commands and voice assistants [...]*” and P7 said: “*[...] there is a technology that uses eye-tracking, and I also know of some peripherals like a keyboard that is also specific for people with mobility problems so that they can use the keyboard with fewer movements.*”.

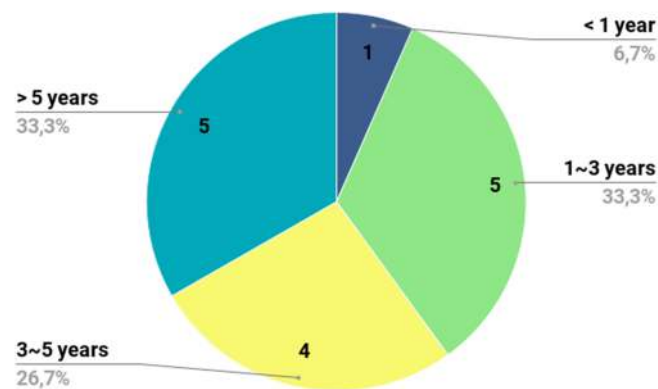


Figure 3: Interviewees' years of experience developing software.

Developers seem not only to understand the general aspects of accessibility but also the aspects concerning how technology can help those who need accessibility. In their responses to other questions, interviewees also highlighted how important they believe it is to consider accessibility aspects in software development, and 94% also responded that they believe that there are few or very few options of accessible software for people who need them.

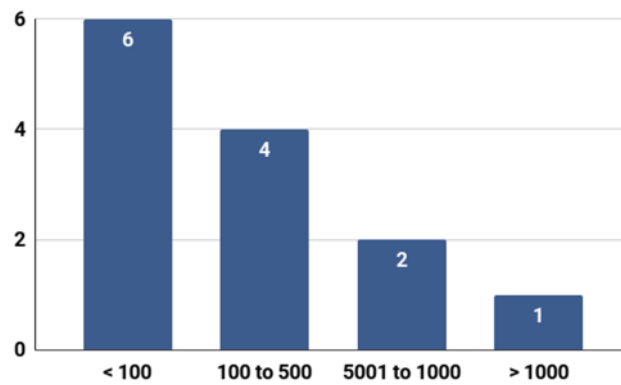


Figure 4: Concentrations of interviewees by organization size according to the number of employees.

4.1.2. Accessibility is Overlooked

Participants all agreed that accessibility is overlooked in the software development process, listing several reasons. We seek, through some questions, to comprehend these reasons and their origins. When asked about the most significant challenges to inserting accessibility in software development, interviewees highlighted several reasons that lead to the neglect of accessibility. The most mentioned challenges were: lack of empathy, lack of interest, and lack of technical knowledge.

As for the lack of interest, P10 argued: “[...] I think the biggest challenge is a paradigm shift, a desire to go and do it. Because it's a job like any other [...]” and P14 commented: “I think the biggest challenge is for people to want it, because I think today few take this into account [...] I think they need to want to do it, because when a person develops a software, if he wants to, he can implement it [...]”.

Some respondents believe that lack of empathy is the biggest challenge for accessible software development. P3 even proposed an analogy: “In everyday life, when you are going to build an establishment, you will think, for example, about the bathroom. You also have to think about the bathroom for people with disabilities, or how to guide a person with disabilities. I think that software development should be the same way [...]”.

4.1.3. Legislation

When asked if they knew of the existence of Brazilian laws that focus on public policies for the development of accessible software products, only one in five interviewees answered yes. There are laws in Brazil that regulate and support digital accessibility (Brasileiro, 2019); however, they are not strongly enforced outside the sphere of digital products offered by government agencies. Respondents believe that more strictly enforced laws and regulations could be a solution to creating more accessible software.

On the subject, P10 said: “Well, I think it's much more in the regulatory field, maybe? From the government, in the sense of imposing obligations [...]”. P14 commented: “I think one of the steps would be laws, which at least oblige to have, at least, a percentage, an accessible part within each software created for the platform, each game... As we don't have that then it's up to the company to want to implement it or not.”. P12 agreed: “[...] some

law that required it, some law that requires a minimum of accessibility for private and public companies.”.

4.2. Educational Aspect

The educational aspect groups the findings related to the academic background of the interviewees, as well as their opinion on the education they have received regarding accessible software development.

4.2.1. Lack of Theoretical and Technical Knowledge

Although, as shown in the previous section, the developers interviewed had general notions about accessibility in computer systems, a recurring theme emerged from the answers to several questions: the lack of technical and theoretical knowledge regarding accessibility in software development. Technical knowledge is considered a set of rules for solving a problem, and it is created from theoretical knowledge (Clarke & Winch, 2004).

A third of the interviewees believe that one of the biggest challenges to accessible software development is the lack of knowledge. P6 commented: *“I believe that, first of all, you need to have people who have this knowledge, because it is not a simple area and, mainly, because there are several types of disabilities that lead to different solutions for the software, so I think having someone or having this prior knowledge [...]”*.

When asked if they knew any accessibility guidelines (such as the WCAG (Caldwell, et al., 2008)), 4 of the 15 respondents answered yes, another three answered yes, but did not remember the guideline's name. The rest of the participants answered not having knowledge about the subject.

4.2.2. Accessibility is Not Taught

We also investigated the academic experience of the participants, seeking to understand if accessibility is a topic of discussion and if it is taught in universities and colleges. All respondents had undergraduate degrees or were still undergraduates in the technology field, such as Computer Science and Computer Engineering. Figure 5 shows the courses of the participants.

We questioned the volunteers if at any point during their academic life, accessibility was discussed in any class. Of the 15 participants, six answered no, and nine answered yes. Of the nine that answered yes, all specified that it was taught very briefly and not in-depth, and seven specified that the only class that taught accessibility was HCI. Figure 6 shows the percentage of each answer.

Still trying to understand how prepared professionals are to develop accessible software products after completing their degrees, we asked if participants believe their education was sufficient to fully develop accessible software. Only two of the respondents answered yes. P3 commented on the question: *“Certainly not, they end up not getting much into this subject or dedicating classes to it. It's more about the superficial of software development, what it needs for it to work.”*.

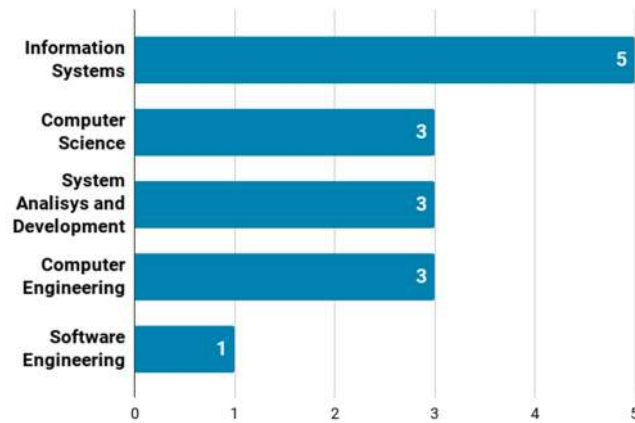


Figure 5: Distribution of participants according to their undergraduate courses.

4.2.3. Investment in Education

From the analysis of the data collected during the interviews, we perceived that accessibility in software development is either not taught or, when taught, it is brief and little in-depth. The interviewees highlighted the lack of education and also that they believe in the need to invest in education for the training of qualified professionals who know the challenges faced by those who need accessibility options and have the skills to create accessible software.

P1 stated: “I think that the entire foundation of education in software development should be concerned about this already. In college, for example, we didn't see anything related unless you take a very specific class [...]”. P9 also shared the same opinion: “I believe solving this problem should start mainly in universities, right? With classes focused on accessibility issues [...]”, P13 said: “I imagine that there should be, perhaps, a subject, something in the curriculum, that is focused on accessibility. When I was in college, I don't remember having something like that [...]”.

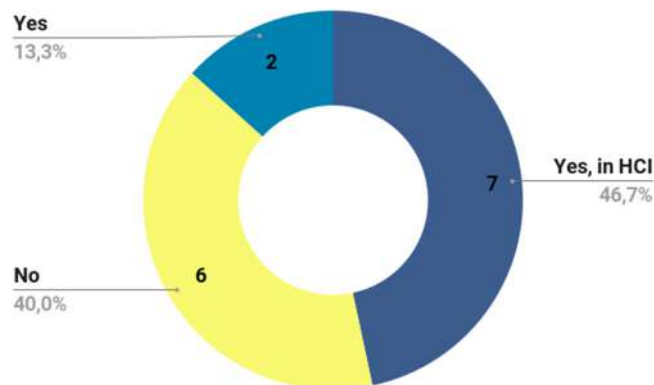


Figure 6: Distribution of participants according to whether they studied accessibility in college or university.

4.3. Organizational Aspect

This aspect groups the findings related to the organizations for which the interviewees work, how and if they address accessibility, and the primary challenges involved in doing so.

4.3.1. Organizations Neglect Accessibility

We investigated whether accessibility is a consideration during software development in organizations where respondents work, and only a third of respondents answered yes. We also asked if the organizations where they work have at least one accessibility specialist, explaining a specialist as a person they would seek to solve any questions regarding accessibility. Only two of the interviewees answered yes.

Software accessibility is neglected in organizations, and understanding the reasons for this is crucial in trying to mitigate this problem. Even the participants who indicated that projects are developed with accessibility concerns in their organizations indicated that perhaps it is only considered in a non-comprehensive way. P3 commented: *“Yes, but not so much. I think in an average way.”*. P5 stated: *“I believe so, but only up to a certain level.”*. Similarly, P6 noted: *“More or less, I think very little well, very little.”*.

4.3.2. Accessibility Costs Time and Money

Interviewees commented on how time is a scarce resource in software development and how urgency and the monetary cost get in the way of accessible development. The participants argued that providing more time for developing accessibility options would result in a more expensive project overall. They also claimed the extra money spent would likely not have an equivalent return, as they consider the demographics that need accessibility too small.

P2 said: *“It is a market that needs a lot of speed to get things done, generally speaking, accessibility is not thought of, the main goal is solving the general problems [...]”*. P7 commented: *“[...] every project I've ever worked on, everything is urgent, everything needs to be fast and making something accessible isn't fast, it costs time, it costs money and most projects don't want this kind of expense of time and money to make something accessible”*. And P3 argued: *“Well, from what I hear from developers and from what I understand, people don't look at that side much. They leave it as a last priority. Maybe because it's a minority, so when you're going to look at numbers, it's easier to look at what brings more profit. So I want to develop software quickly, I need to make money with it, I need to have a return, and when you think that people with disabilities are a minority, you won't worry about that so much.”*.

4.3.3. Training of Professionals

When we asked participants if the organizations they work for offer accessible software development training, they all said no. However, the interviewees believe that offering training within organizations is one of the ways to ensure the development of more software with accessibility concerns. P9 said: *“[...] I think that conducting training courses in companies is very interesting to increase this visibility for accessibility.”*. P15 stated: *“I believe that some mini-course, or something like that in the company. I think it should happen for everyone to understand the real need for accessibility in the implementation of*

software.”. P13 argued: “[...] on the part of the company, I don't remember having worked in one that offered training on accessibility, but this is one of the paths that I believe are necessary.”.

4.3.4. Accessibility as a Requirement

We explored whether developers believe accessibility in software development should be a requirement elicited from stakeholders or if those who develop software should consider accessibility an essential step. The answers are shown in Figure 7. Seven answered it should be a requirement, six answered it should be an essential step, and two believe the correct answer is a combination of both.

Some interviewees believe that treating accessibility as a requirement would increase the number of accessible software available; as being an elicited requirement, the necessary development time would be taken into account and make it obligatory for the developer to implement it. P10 said: “I think it has to be a requirement, because if it is up to management to decide or develop, for other issues like the tight deadline or lack of resources, it may be something that is relegated to a future moment ... It is left for later and ends up not happening. So if it is a requirement, if it is within the project's scope, then it is possible to demand, and it is necessary to develop.”. P15 argued: “I believe it has to be treated as a requirement because that way everyone will have to implement it.”.

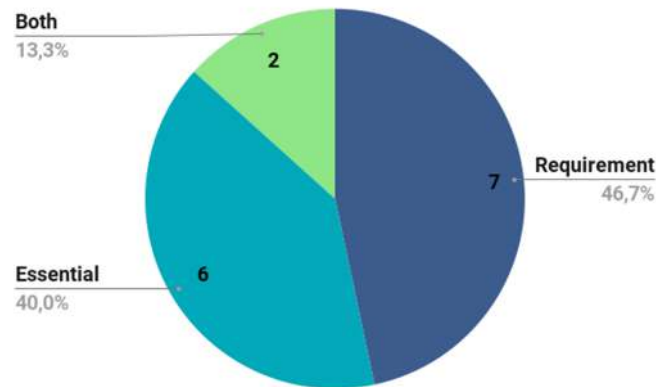


Figure 7: Answers on whether accessibility should be treated as a requirement or an essential step during software development.

5. DISCUSSION

This section presents a discussion of the results found, which will be presented divided into the same aspects. In the end, we list a series of recommendations that we believe should be adopted to promote the creation of more accessible software.

5.1. Personal Aspect

Our results show that the Brazilian software developer, considering the subgroup interviewed, understands what accessibility is, understands the importance of creating accessible software, and, most importantly, understands how people who need accessibility interact with electronic devices. Almost all interviewees displayed having a general

understanding of these three aspects, indicating an improvement compared with a previous study (Freire et al., 2008) from over a decade ago (2008) that surveyed professionals involved in web development projects in Brazil. In said study, 27.57% of the participants did know a person who is blind could use the web but did not know how, and 3.1% did not know a blind person could use the web whatsoever. This improvement shows that accessibility awareness has increased among software development professionals in recent years, a good sign that the needs of people with disabilities have been more widely debated.

However, on par with previous work (Leite et al., 2021), our results indicate that most developers do not have the necessary knowledge to implement accessible software. The participants indicated that the main reasons for this lack of knowledge are that they were not taught accessibility in college or university and that the organizations they work for do not offer accessible development training. Excluding formal education and training offered by the organizations, only personal interest would remain as a way of acquiring the technical knowledge necessary for the implementation of accessible software. This finding is corroborated by the fact that only 4 of the 15 interviewees could name, when asked, an accessibility guideline (such as the WCAG). Although knowing accessibility guidelines does not directly correspond to knowing how to implement accessibility, acquiring knowledge about some of them is inevitable during the process of learning and consulting accessibility documentation; especially the WCAG, considered the *de facto* standard for accessibility (Herstad et al., 2016) and used not only for the web (platform for which it is intended) but also for other platforms.

5.2. Educational Aspect

Participants indicated that they had little to no contact, in their academic trajectories, with the development of accessible software. Human-Computer Interaction was cited as the only class in college or university to cover this subject, albeit briefly and not focused on the implementation aspect of it. Furthermore, only two interviewees believed their education to be enough to develop accessible software. This scenario shows that educational institutions also overlook accessibility, which means new professionals are coming out of their training without these skills. Developers interviewed understand and highlighted the importance of teaching accessibility in colleges and universities, suggesting that accessibility should be more addressed in the content of already existing classes or that it could become a class of its own. These findings indicate the need to rethink the curriculum of academic courses, seeking ways to integrate accessibility education to the knowledge they already receive.

5.3. Organizational Aspect

From an organizational point of view, we found that organizations' neglect of accessible development is evident. Only a third of respondents answered that the organizations they work for implement accessibility aspects in the software products they develop. Accessibility, when it exists, is superficial or appears only at the end of the primary development cycle or even in future improvement cycles. Moreover, only two respondents indicated that their companies have at least one accessibility specialist, and none answered that the company they work for offers accessible software development training.

Working in an organization, the software developer is not the professional responsible for the project decisions, but only for implementing the elicited features. Developing accessible software must be a project-level decision and cannot be treated as a decision the developer should make. Although other studies (Bi et al., 2021; Antonelli et al., 2018) turn

to developers searching for reasons and solutions for the problem of low adoption of accessibility concerns in software products, choosing to implement it or not is a decision that comes from more strategic levels in the software development process. The developer's experience with accessibility, their empathy towards people with disabilities, and their motivations for implementing accessibility is a potential that goes untapped if the project they are working on does not have accessibility in the scope. Unless accessibility is a defined part of the project, the developer is not given the necessary time and resources to implement it.

Implementing accessibility, like any other form of software development, is a hard skill that, while developers can learn in formal education, can be learned as needed. In an environment where new technologies are emerging continuously, the ability to learn new things fast is an essential part of the software developer job. If implementing accessibility is defined in the project, the developer can acquire the necessary knowledge through training that could be offered by the organization or acquired on their own through specific courses, books, or online material. The developer's knowledge of accessible development is not as significant a barrier as the barrier imposed by the project itself. Understanding the reasons that lead the organizations to disregard accessibility in the projects they develop is extremely important to propose solutions for the problem.

According to interviewees, the most significant factor that makes it difficult for organizations to adopt accessibility concerns is the cost associated with its implementation. This cost derives from hiring professionals with specific knowledge and skills or training current professionals, and the longer time for planning, implementing, testing, and validating projects with accessibility concerns. Our results indicate that in the projects developers are involved in their organizations, deadlines are often tight, and agile methodologies imply shorter development cycles that prioritize deliveries considered to be of greater value.

For accessibility to be within the scope of projects, it must either be considered essential by project management or be elicited from stakeholders. This determination depends on the software stakeholders considering that accessibility is a requirement for the product they want or on the organizations to recognize the importance of accessibility, enforce it, and implement it. Either way, it implies changes at all stages of the software development process, which often translates to extra costs.

The W3C (World Wide Web Consortium), maintainer of the WCAG, has a document that comments on the financial factors involved in implementing accessibility in organizations (W3C W. A., 2012). This document clarifies that the cost of implementing accessibility is only high at the beginning. However, since accessibility is usually implemented at the level of the entire organization and not just a project, the cost per project of implementing accessibility ends up being just a minor percentage. This percentage can get even smaller if, for each project, accessibility is incorporated from the beginning of the development process.

It is important to comment on the regulatory aspect that falls on the government; many participants mentioned believing that the way to make accessibility mandatory in software development is through more specific laws aimed at software development and its enforcement by the responsible bodies. There is a clear need for the creation of such laws, as the lack of legal requirement is one of the reasons why organizations do not consider accessibility when building their software products. We believe that once legislation on accessible software begins to be enforced in public and private organizations, all other identified barriers tend to be weakened.

5.4. Recommendations

After analyzing and understanding the problem, below we list a series of recommendations for actions to be taken that we believe are necessary for the dissolution of barriers that interfere in the production of accessible software. The recommendations are listed and explained below:

- **Accessibility Education:** Educational institutions that train software development professionals must include education on accessibility in their academic curricula. Ideally, each class should explore how accessibility can be embedded within the content being taught. As well as having specific classes focused on accessibility in software as a whole.
- **Incorporation into Organizations:** Organizations must recognize the importance of accessibility and make it essential in the development of their software products. The user experience must be thought of from the point of view of all users, without excluding people with disabilities, and accessibility must be considered from the conception of the software to its maintenance. With accessibility becoming an essential requirement, the organization will be able to demand its implementation and evaluate it.
- **Training in Organizations:** Once accessibility is incorporated in organizations, they must provide the necessary training for professionals involved in the software development process to acquire or renew their knowledge on the subject. Receiving this training within the organization they work in will allow professionals to learn about accessibility applied to their internal processes and what changes will be made to allow for the implementation of accessibility.
- **Legislation:** Stricter laws and regulations aimed at the development of accessible software must be created and enforced to guarantee the rights of the people who need it, thus making public and private organizations obligated to create their software products always incorporating accessibility concerns. Only with strict enforcement and sanctions will it be possible to ensure compliance with such legal obligations.

6. FINAL CONSIDERATIONS

This study presented a general understanding of the relationship between the Brazilian software developer and the development of accessible software. Making more accessible software available is a multi-faceted challenge that involves changes at various stages in the software industry. It is evident the need to invest in education to train developers capable of doing so. However, organizational factors play a major role in defining whether accessibility will be addressed or not.

Solving the organizational barrier appears to be the first step toward solving the other barriers. It is our belief that as soon as organizations start, for whatever reason, to include accessibility in their products, developers will need to learn how to implement it and look for ways to do so. Furthermore, it would push educational institutions to realize the importance of teaching accessible development to their students, as they would need it in their future professional careers.

We believe that accessibility should be treated as a crucial step in the software process, being considered in all stages of development. Ignoring accessibility is denying people who need it their rights, and it is a problem that must be treated with the expected seriousness.

Implementing accessibility in software projects can increase the generated profit directly and indirectly. Having accessibility-friendly software expands the potential market share, allowing it to reach more people it would not reach otherwise. This increase in public can directly increase profit, as the global market of people with disabilities is over 1 billion people with a spending power of over 6 trillion dollars (W3C W. A., 2018). In indirect ways, accessibility can improve the product's position in search engines which typically give higher priority to accessible content, it can increase usability for all users, and increase the positive image of the software (W3C W. A., 2012). It is up to organizations and software stakeholders to recognize the hidden market they will have access to if they make their software products with accessibility in mind, and do so not only for the financial aspect but also for understanding the social aspect of allowing the inclusion of those who need it.

For future work, we intend to investigate, in more detail, the business characteristics of organizations to understand their choices regarding accessible development better. Interviewing or surveying managers and directors and getting their positions regarding including accessibility in their projects can give better insight into the reality of the business perspective.

We also want to investigate the relationship between organizations that have employees with disabilities and the implementation of accessible software products. Our assumption is that companies that hire people with disabilities have a higher level of awareness of the inclusion of accessibility in their own products.

We also aim to conduct studies to investigate the reasons that lead many academic courses not to include accessibility as part of the curriculum, and the reasons for the ones that do include it only touch on the subject so briefly. We want to understand what criteria are used in the creation of their academic curriculum and if the non-inclusion of accessibility has any relation to the fact that the organizations that will employ the professionals formed by them do not require knowledge in accessibility.

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