Journal of Software Engineering Research and Development, 2025, 14:1, doi: 10.5753/jserd.2026.5887

Specifying Accessibility Requirements with Personas, WCAG, US, and BDD Scenarios: Insights from Two Case Studies

Renata Vinadé [**Pontifical Catholic University of Rio Grande do Sul** | ***renata.vinade@edu.pucrs.br***]
Natalya Goelzer [**Pontifical Catholic University of Rio Grande do Sul** | ***natalya.goelzer@edu.pucrs.br***]
Sabrina Marczak [**Pontifical Catholic University of Rio Grande do Sul** | ***sabrina.marczak@pucrs.br***]

Abstract

Accessibility is essential for inclusive digital experiences, yet it is often overlooked in early stages of software development. This paper presents two empirical studies focused on improving how accessibility requirements are specified. In the first study, undergraduate Software Engineering students explored accessibility principles through guided activities and questionnaires. The second study evaluated a structured method combining Personas, User Stories, Behavior-Driven Development (BDD), and WCAG guidelines. Participants applied the method to specify accessibility features in real scenarios. The findings show that although initial knowledge was limited, structured interventions led to more precise, WCAG-aligned, and testable requirements. These results highlight the value of embedding accessibility into software engineering education and demonstrate the effectiveness of combining user-centered design with formal specification techniques.

Keywords: Software Engineering, Non-functional Requirements, Accessibility Requirements, Behavior-Driven Development, WCAG, Personas, Case Study

1 Introduction

Disability is an intrinsic aspect of the human experience, affecting nearly everyone at some point in life (WHO, 2024). Globally, an estimated 1.3 billion people, representing about 16% of the population, live with some form of disability, including visual, auditory, physical, cognitive, or learning impairments (WHO, 2024). In Brazil, over 17 million individuals aged two and older report having a disability (IBGE, 2022). Despite technological advancements, both physical and digital environments continue to present barriers that hinder the full participation of people with disabilities (WHO, 2024). Many software systems are still developed based on assumptions that users can easily see, hear, or operate input devices, disregarding the diversity of user abilities.

Digital accessibility aims to ensure that individuals with disabilities can access the same digital services and information as others (Info. Society and Media, 2005; Yusop et al., 2016). Standards such as the Web Content Accessibility Guidelines (WCAG) and the Accessible Rich Internet Applications (ARIA) suite provide essential guidelines for inclusive system design. Moreover, the ISO/IEC 25010 standard defines accessibility as the degree to which a system can be used by people with diverse capabilities to achieve specific goals in a given context (ISO, 2011). Although research and practice have advanced (Acosta-Vargas et al., 2017; Darvishy, 2017; Vendome et al., 2019; Alshayban et al., 2020; Chen et al., 2020; Nogueira and Gonçalves, 2021; Pinheiro and Marques, 2021), only some development teams incorporate accessibility into their processes (Richards et al., 2012; de Oliveira et al., 2018; Paiva et al., 2021). One ongoing issue is the tendency to treat accessibility as a final-stage enhancement rather than a fundamental design concern. A crucial step in software development is the specification of functional and non-functional requirements (NFRs). While functional requirements describe what a system should do, NFRs define how it should behave, covering aspects such as performance, usability, and accessibility (Kotonya and Sommerville, 1998; Mylopoulos et al., 1992). However, accessibility as an NFR is often neglected or weakly defined, partly due to limited awareness among developers and stakeholders (Domah and Mitropoulos, 2015). This work aims to promote a better understanding of how accessibility, as a NFRs, can be explicitly described in connection with system functionalities. To achieve this, we propose a structured method that uses Personas and WCAG to contextualize user limitations and needs. These are then translated into User Stories (US) and Behavior-Driven Development (BDD) scenarios, enabling the specification of expected accessible behavior in a structured and testable form. To explore this approach, we conducted two case studies as part of an exploratory research project focused on supporting the early integration of accessibility into software development. In both studies, participants were undergraduate software engineering students in their fourth or fifth semester who were either interning or working in information technology (IT)-related roles. The first study aimed to identify participants' baseline knowledge, misconceptions, and challenges related to accessibility. This initial intervention, based on pre- and post-activity questionnaires and collaborative exercises, revealed that participants had an intuitive but often superficial understanding of accessibility principles. These findings informed the design of the second study, which implemented the proposed structured method combining Personas, WCAG, US, and BDD to guide participants in formalizing accessibility-related non-functional requirements.Given the similar background of participants in both studies, the research followed a sequential rationale. The first study revealed critical educational gaps, while the second addressed those gaps by implementing and evaluating structured instructional strategies. This progression allowed us to refine our intervention and assess its impact on students with comparable levels of experience. Together, the studies contribute to understanding how structured guidance can support the transition from abstract accessibility principles to concrete, testable specifications. The following research questions guided each study:

Study 1 – Understanding Baseline Knowledge and Gaps:

[**RQ1**] How do practical experience and theoretical knowledge influence software engineering students' approach to accessibility?
[**RQ2**] What improvements can be made to educational strategies and resources to better prepare future professionals for incorporating accessibility into software development?

Study 2 – Applying Structured Guidance to Specify Accessibility Requirements:

[**RQ1**] Is it possible to specify non-functional accessibility requirements in the form of US and BDD scenarios?
[**RQ2**] Does the combination of US, BDD scenarios, and WCAG support the elicitation of requirements that more effectively address accessibility needs in the system?

The results from both studies revealed a significant gap between students' awareness of accessibility and their ability to implement it effectively. Initially, students relied on intuition rather than formal standards when specifying accessibility requirements. In the second study, after guided interventions, students demonstrated progress in articulating clearer and more accurate requirements. The combined use of Personas, US, BDD scenarios, and WCAG proved to be a promising strategy for bridging the gap between theoretical understanding and the practical application of accessibility principles in the requirement specification process. This work extends prior research by reporting a new case study that explores how undergraduate software engineering students specify accessibility requirements using structured approaches. It introduces and evaluates the combined use of Personas, User Stories, BDD, and WCAG as a framework to support the articulation of accessibility-related requirements.

Together, these contributions advance our understanding of how to operationalize accessibility requirements early in the software development lifecycle. The remainder of this paper is organized as follows: Section 2 provides background information on accessibility, including key concepts and relevant guidelines. Section 3 outlines the research design adopted in the studies. Section 4 describes the first study, detailing its methodology, activity design, and results. Section 5 presents the second study, which investigates the use of Personas, WCAG, User Stories, and BDD in the specification of accessibility requirements. Finally, Section 7 offers concluding remarks and discusses directions for future work.

2 Background

2.1 Accessibility

The concept of accessibility has evolved since the 1950s, when it was primarily associated with building construction. At that time, the emphasis was placed on adapting existing buildings and designing new ones to accommodate people with disabilities (PWD)(Case, 2008; Cakir, 2009; Abascal et al., 2016). More recently, the definition of accessibility has expanded to include digital environments. Digital accessibility refers to the practice of ensuring that PWD can access the same digital services and content as others (Info. Society and Media, 2005; Yusop et al., 2016), which is increasingly important as digital technologies become essential for daily life. Disability is an intrinsic aspect of human experience that may affect almost everyone at some point, either temporarily or permanently (WHO, 2024). An estimated 1.3 billion people, or roughly 16% of the global population, live with some form of disability, including visual, auditory, physical, speech, cognitive, or learning impairments (WHO, 2024). In Brazil, the 2019 National Health Survey reported that 17.3 million individuals (about 8.4% of those aged two and older) have a disability (IBGE, 2022). The prevalence of disability increases steadily with age: people over 60 are especially susceptible to visual, cognitive, motor, and auditory impairments (IBGE, 2012). According to United Nations projections, approximately 25% of Brazil's population will be over 60 by 2050 (United Nations, 2022), further increasing the demand for accessible digital solutions.

Governments and organizations around the world have acknowledged the importance of accessibility. For instance, the United Nations adopted the Convention on the Rights of Persons with Disabilities in 2006 to ensure equal rights and freedoms for all individuals with disabilities. This treaty outlines how to apply human rights in ways that are inclusive and protective of PWD. Brazil demonstrated its commitment to these rights by signing the Convention in 2007 and formally ratifying it in 2008 (United Nations, 2023).

2.2 The Web Content Accessibility Guidelines (WCAG)

There are several international standards that guide digital accessibility and should be referenced by software development teams to ensure content is accessible to people with a variety of disabilities. The development of these guidelines is led by the World Wide Web Consortium (W3C), an international organization dedicated to establishing web standards. The W3C's goal is to maximize the potential of the Web by making it accessible to all people, regardless of their abilities or circumstances (W3C, 2024). In this context, the Web Content Accessibility Guidelines (WCAG) have become the universal standard for digital content accessibility. WCAG encompasses various types of content, such as dynamic content, multimedia, mobile applications, and non-web information and communication technologies. Its purpose is to ensure that people with disabilities can access and

Table 1. Examples of WCAG criteria (W3C, 2018)

WCAG #	Criteria Name	Level	Principle
1.1.1	Non-text Content	A	Perceivable
2.2.3	No Timing	AAA	Operable
3.2.3	Consistent Navigation	AA	Understandable
4.1.2	Name, Role, Value	A	Robust

understand all web content, including text, images, sounds, and code (W3C, 2024).

The WCAG is based on four guiding principles: perceivable, operable, understandable, and robust. See Table 8 for examples. These principles direct the development of accessible web content by aiming to make it perceivable to users, simple to operate, clear in its information and functionality, and robust enough to operate with different user agents.

Over time, the WCAG has evolved from version 2.1 to version 2.2, which includes 85 success criteria. These criteria are divided into three levels of conformance: A, AA, and AAA. While meeting the highest level of conformance does not guarantee complete accessibility for individuals with specific disabilities, such as cognitive or language impairments, it sets a standard for accessibility and demonstrates a commitment to inclusivity (W3C, 2018). Ongoing efforts to improve accessibility and consultation with people with disabilities are essential to address individual needs effectively.

By following the WCAG, developers have access to a comprehensive framework for ensuring digital accessibility. This set of recommendations enables individuals, organizations, and governments to promote inclusive experiences, broadening access to information and technology. However, despite these established guidelines, the persistent challenge lies in the inconsistent or incomplete adoption of WCAG by many development teams. As a result, numerous websites and applications still fail to meet even basic accessibility requirements, leaving large segments of the population, particularly those with complex or less-visible disabilities, underserved. This gap highlights the importance of not only understanding WCAG but also actively integrating its principles into everyday design and software development practices to foster truly inclusive digital experiences.

2.3 Non-functional Requirements

One of the first stages of software development is the specification of requirements, which guide the design and implementation of the solution. These requirements are typically grouped into two main categories: functional requirements, which describe what the system should do (its behaviors and features), and non-functional requirements (NFRs), which define how the system should behave under certain conditions, addressing aspects such as performance, security, usability, and accessibility (Kotonya and Sommerville, 1998).

Among the various non-functional attributes, accessibility has gained increasing relevance in recent years. Beyond being a legal obligation, it also represents an ethical and practical commitment to ensuring that digital services are inclusive and usable by all individuals, including those with disabilities (National Disability Authority, 2020; Paiva et al., 2021). Accessibility, as a non-functional requirement, should be addressed from the early stages of development and throughout the software lifecycle. Although validation through testing is essential, it is the proper specification of accessibility requirements that lays the groundwork for inclusive system behavior (Schulz and Fritsch, 2014). The importance of NFRs is widely acknowledged in the literature, as they are essential for user satisfaction and system quality. End-users evaluate not only the presence of functionalities but also how those functionalities are delivered, considering criteria such as performance, scalability, and accessibility (Glinz, 2007; de Castro Pinto et al., 2022). In the case of accessibility, compliance with international standards such as ISO/IEC 25010 and guidelines like the WCAG adds layers of technical, legal, and social complexity (Kiyavitskaya et al., 2008; Hoffmann et al., 2012).However, specifying NFRs, especially accessibility, remains a significant challenge. These requirements tend to be broad, cross-cutting, and often ambiguous, posing difficulties for clear definition, integration with functional requirements, and objective validation. Common issues include unclear scope, high volatility, and the absence of concrete evaluation criteria (Ullah et al., 2011; Matoussi and Laleau, 2008).

A particularly critical difficulty for development teams lies in understanding how NFRs, such as accessibility, interact with functional requirements. Developers often struggle to conceptualize how accessibility manifests within the actual system behavior and how it influences user interactions. While functional requirements describe visible features, accessibility operates as an underlying quality that must permeate each feature, making its specification less intuitive. To address this gap, it is essential to promote a better understanding of how accessibility is not a standalone attribute, but must be reflected in the way functionalities are designed, implemented, and presented. Therefore, teams should learn to describe how accessibility principles behave in interaction with the system's features, identifying how standards like WCAG map to specific functionality and how users with different needs will experience those interactions.

2.4 Specifying Requirements with BDD

To support the process of specifying requirements, US and BDD Scenarios are widely used as a lightweight, user-centered way to express requirements. They reflect a shared understanding between customers, who have the right to obtain the most value from each programming effort, and developers, who require clarity about what is expected. A user story describes functionality that is valuable to a user or purchaser of the system and should be written in business language rather than technical jargon. This approach enables the customer team to prioritize features for iterations and releases. The format popularized by (Cohn, 2004), '**As a** [role], **I want** [function], **so that** [business value]', captures the core elements of a requirement: who it is for, what is expected, and why it matters. Lucassen Lucassen et al. (2015) states that this structure is effective because it concisely expresses the essence of a requirement from the client's perspective.

However, user stories often lack sufficient detail to fully guide development and validation activities. To address this, acceptance tests are introduced to express additional requirement details that do not fit within the user story model (Gart-

```
Given Western line trains from Emu Plains
leave Parramatta for Town Hall at 7:58, 8:00,
8:02, 8:11
When I want to travel from Parramatta to
Town Hall at 8:00
Then I should be told to take the 8:02 train
```

Figure 1. Scenario example (adapted from Smart, 2014).

ner, 2012). One effective way to express these acceptance tests is through Behavior-Driven Development (BDD) scenarios. Scenarios, in general, are hypothetical narratives that support reasoning about complex systems and enhance learning through active exploration (Alexander and Maiden, 2004; Kaner, 2003). In this context, a scenario represents a specific instance of a use case, detailing a concrete path through the system model. Within the BDD approach, scenarios play a central role as a business-readable format to describe and model system behavior. As noted by Smart (Smart, 2014), using conversations and concrete examples to specify the expected behavior of the system is a fundamental practice in BDD. Practitioners collaborate with users to identify examples that illustrate the features being requested, and these scenarios serve as the basis for acceptance tests (Santos et al., 2015). To standardize the structure of these requirements, the Gherkin language is used, which follows the "**Given-When-Then**" format: Given describes the preconditions, When represents the user action, and Then defines the expected outcome. This structure ensures clarity and precision in documenting requirements (see Figure 1). Using the 'Given-When-Then' format, BDD scenarios promote a shared understanding of the intended functionalities. However, to ensure effectiveness, these scenarios must adhere to quality attributes such as clarity, completeness, and applicability Goelzer and Marczak (2024). Oliveira et al. Oliveira et al. (2019) state that a well-written scenario should exhibit eight key attributes: essential, focused, singular, clear, complete, unique, ubiquitous, and integrous. These characteristics are fundamental to ensuring that the scenarios are both understandable and applicable across all relevant contexts. For the specification of requirements in scenario format, Smart Smart (2014) describes the steps involved in a BDD process, as outlined below:

1. **Discover stage:** During this early stage, the goal is to gain an overall understanding of the product, mapping the user journey and organizing features according to user activities. It is also an opportunity to reflect on the project's purpose and identify who will be impacted, ensuring alignment between what is being developed and the actual business needs.
2. **Define stage:** The team starts to have more concrete conversations around specific business rules and examples of how the user would interact with the system.
3. **Formalize stage:** After identifying the main business rules and examples, these elements are formalized in Gherkin format by the team (generally by the test engineer in collaboration with a business analyst or tester). Our research is focused in this stage, as the analysis centers on how BDD is often used for writing non-functional requirements related to system accessibility.
4. **Automate and Deliver stages:** This is the stage where the team implements the missing functionality, and these Gherkin scenarios are automated.

North (North, 2020) proposed a structure that combines both organization and flexibility, making BDD accessible to all participants involved in the software development process, including non-technical stakeholders. The use of natural language in scenario writing enables accessibility requirements to be collaboratively discussed and refined, fostering a shared understanding of how the system should behave to meet the diverse needs of its users. This collaborative approach enhances communication and ensures that accessibility considerations are integrated into the design from the very beginning. Given the need to document accessibility from the early stages of a project, BDD emerges as a robust approach to guide the elicitation of accessibility-related non-functional requirements.

In the scope of this study, BDD scenarios will be used to describe the system's accessible behavior by incorporating guidelines, such as those of the WCAG, into the functionalities. By describing accessible behavior through BDD, it promotes an understanding of accessibility as an integral part of the system's expected behavior, rather than as a separate or optional requirement. This approach allows the team to better understand how non-functional requirements, such as accessibility, interact with functional requirements, promoting more inclusive development in line with quality and compliance standards.

3 Research Design Overview

This study follows an exploratory research design composed of two case studies conducted in educational settings with undergraduate Software Engineering students. The goal was to investigate how SE students understand and apply accessibility-related concepts and how instructional interventions can support the specification of accessibility requirements during early stages of software development.

The first study was designed to assess students' foundational knowledge of accessibility and their ability to identify relevant requirements using realistic personas in a controlled classroom activity. The second study then strategically built upon the deficiencies identified in the first, introducing a comprehensive structured method that integrates Personas, US, BDD, and WCAG to formalize and specify non-functional accessibility requirements. Both studies used mixed-methods approaches, combining quantitative and qualitative data sources, including questionnaires, classroom observations, and artifacts produced by participants. While conducted in academic environments, the activities were carefully designed to emulate real-world software development tasks. **The two cycles are connected by a common goal: to foster students' ability to translate abstract accessibility principles into concrete, testable software specifications.** In Study 1, 53 students participated—38 reported experience through internships or professional

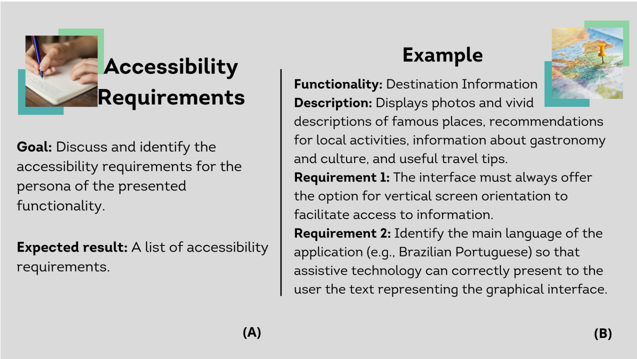

Figure 2. Student Task Output Example

activities in IT. In Study 2, a separate cohort of 60 students participated, with 51 reporting similar work or internship experience. Each study had a distinct participant group. Although data on the length of practical experience were not collected, most students in both groups had direct exposure to software development environments. According to Falessi et al. (2018), involving students in software engineering experiments is a valid simplification of reality in academic settings and contributes meaningfully to the advancement of software engineering research.

3.1 Research Methodology

We conducted both cycles as case studies, aligning with best practices for evaluating accessibility knowledge and requirements elicitation. Each study involved a different cohort of undergraduate SE students at a Brazilian university, many already engaged in internships or entry-level roles.

The **first case study** focused on understanding students' prior knowledge of accessibility and their approach to requirements specification. Participants completed pre- and post-activity questionnaires and engaged in a collaborative design task based on the fictional travel application TravelMate, designed to simulate a real-world travel platform. The selected feature "Destination Information" included interface elements such as photos and descriptions of landmarks, travel tips, and recommendations. Students were presented with a textual description of the feature and, guided by two personas with distinct accessibility needs, were asked to specify requirements for the "Destination Information" functionality (Figure 2). The activity was structured into three phases over two nonconsecutive class sessions: (i) a baseline questionnaire and introductory lecture on accessibility; (ii) a group specification task based on the TravelMate interface and personas; and (iii) a final reflection stage with individual and group questionnaires. The data collected allowed us to analyze students' familiarity with accessibility concepts, perceived challenges, and confidence in addressing inclusive design.

The **second study** investigated how another cohort of students applied accessibility principles using BDD scenarios aligned with WCAG standards. This three-day activity combined lectures, practice sessions, and structured reflection. Building on the previous cycle, this study introduced a structured method for accessibility requirement specification. Participants worked with the same TravelMate feature and a commercial app, using a reverse engineering approach: based on the interface of the commercial application, they formalized how the system should behave to be inclusive and accessible. The specification task integrated US, BDD, and WCAG.

As in the first study, participants analyzed the user interface and used personas to guide requirement elicitation. However, in the second study, requirements were documented in a structured form. The activity spanned three class sessions: (i) foundational lecture, initial questionnaire, and group activity with Personas, US, BDD; (ii) targeted instructional intervention on WCAG and BDD, with group reflection; (iii) structured specification task for a commercial travel app, followed by individual and group questionnaires. Participants advanced through the Discover, Define, and Formalize stages of BDD, using User Stories and Gherkin-based scenarios to express accessibility-related behaviors. Data collection included questionnaires at multiple stages, classroom observations, and detailed artifact analysis. This design allowed comparison of students' outputs before and after instructional intervention, evaluation of how the combined use of personas, WCAG, and BDD contributed to articulating accessibility as a non-functional requirement. Artifact quality was analyzed using predefined criteria, clarity, WCAG alignment, identification of persona-specific needs.

3.1.1 Instruments and Materials

To support practical activities, both studies provided participants with instructional materials that simulated realistic requirements elicitation, utilizing a combination of questionnaires, personas, and software specification tasks.

3.1.2 TravelMate

In both studies, students worked with a fictional web application named TravelMate, designed by the research team to simulate real-world travel platforms. This application served as the foundation for requirements elicitation activities. The goal was to engage participants in identifying accessibility-related requirements by observing and interpreting interface elements of a predefined functionality. The analyzed feature, "Destination Information," included visual and textual content about tourist attractions, recommendations, and tips. Instead of requiring development from scratch, participants were provided a description and asked to specify requirements for the provided personas, focusing on accessibility. In Study 1, requirements were written freely, guided only by the personas and understanding of accessibility; in Study 2, students produced structured outputs as User Stories and BDD scenarios.

3.1.3 Personas

To contextualize the requirements, participants used two personas adapted from the W3C Web Accessibility Initiative Stories of Web Users, which were the same in both studies.

Persona 1 - Maria, a 70-year-old retired nurse who enjoys traveling, cooking, and reading. She experiences arthritis, which complicates the use of digital devices, and concentration difficulties that hinder interaction with complex

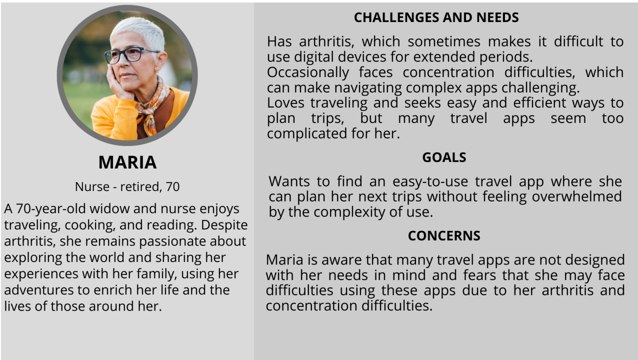

Figure 3. Persona 1 – Maria

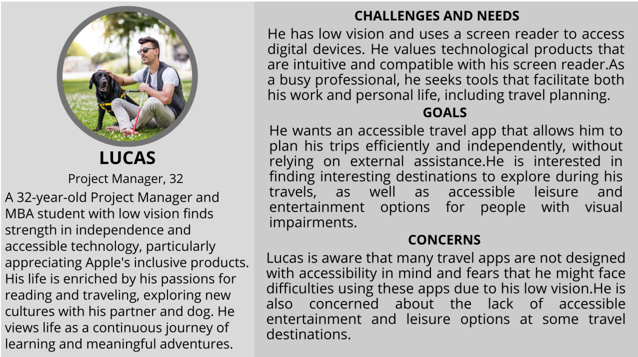

Figure 4. Persona 2 – Lucas

applications. She seeks a user-friendly travel app that accommodates her physical and cognitive needs (Figure 3).

Persona 2 - Lucas, a 32-year-old project manager with low vision, who relies on screen readers. Passionate about travel, he requires intuitive, assistive-tech-compatible apps to support independent travel planning and provide information on accessible destinations and leisure activities (Figure 4).

Working with these personas, student groups identified accessibility needs and formulated design requirements. This process encouraged students to apply accessibility principles in a scenario, deepening their engagement with inclusive design.

3.1.4 Instructional Materials

To support practical activities, participants received comprehensive instructional materials that simulated realistic requirements elicitation, including questionnaires, personas, software specification tasks, and lectures covering WCAG principles, assistive technologies, and legal frameworks. All this instructional content was developed by the first author, reviewed by the second author (an expert in both professional and academic BDD) and validated by the third author, an expert in accessibility and software engineering education. A complete replication package containing all materials is available (see Section Availability of Materials).

3.2 Questionnaire Design

The design of the survey instruments used in this research followed the guidelines proposed by Kitchenham and Pfleeger Kitchenham and Pfleeger (2007). Prior to deployment, all questionnaires were reviewed by three researchers to ensure clarity, relevance, and alignment with the study objectives.

These instruments included both closed (Likert scale) and open-ended questions. Feedback from this review process informed iterative revisions, resulting in the finalized versions applied in both empirical studies. In the first study, the survey was structured into five sections and administered across two days of activities. The initial section gathered demographic data and assessed students' familiarity with accessibility concepts, including laws, guidelines such as WCAG, and assistive technologies (Table 2). The subsequent section presented two practical scenarios for a collaborative activity, followed by related questions. On the following day, students completed an individual instrument to evaluate their perceived difficulty and confidence regarding the task (Table 3). Group questionnaires were also used to investigate the reasoning and strategies employed to derive accessibility requirements from the personas (Table 4).

The second study expanded the original survey design to better capture participants' understanding throughout a structured instructional sequence that included BDD and WCAG. Four distinct questionnaires were used: a baseline questionnaire (Table 6) assessing initial knowledge and prior experience; a post-lecture reflection (Table 7) exploring challenges faced and the impact of instruction; an individual questionnaire (Table 8) evaluating participants' application of WCAG during a practical task; and a final group questionnaire (Table 9) focused on collective strategies and reflections. This multi-instrument approach enabled monitoring of learning progression over three sessions. Compared to the first study, the second introduced additional questions that assessed participants' familiarity with BDD, their perception of WCAG's clarity and usefulness, and their ability to integrate accessibility standards into structured requirement specifications. Moreover, the inclusion of a second group questionnaire after the WCAG-based task allowed for deeper insight into team-level decision-making and learning outcomes. These enhancements were essential for evaluating the pedagogical effects of the instructional content and the practical application of accessibility principles.

4 First Study

4.1 Activity Design and Implementation

To support students in understanding accessibility within software development, a structured activity was implemented in an undergraduate course. Centered on the TravelMate case, it aimed to promote awareness of inclusive digital services for users with diverse needs. By combining theory with realistic and practical design tasks, accessibility was framed as a core requirement in software engineering. Conducted over two nonconsecutive days, the activity involved collaborative specification of accessibility requirements based on personas and unfolded in three sequential instructional steps (Figure 5).

Step 1 – Pre-Activity (Day 1: Individual Questionnaire and Lecture): Students first completed an individual questionnaire (Table 2) designed to assess their prior knowledge

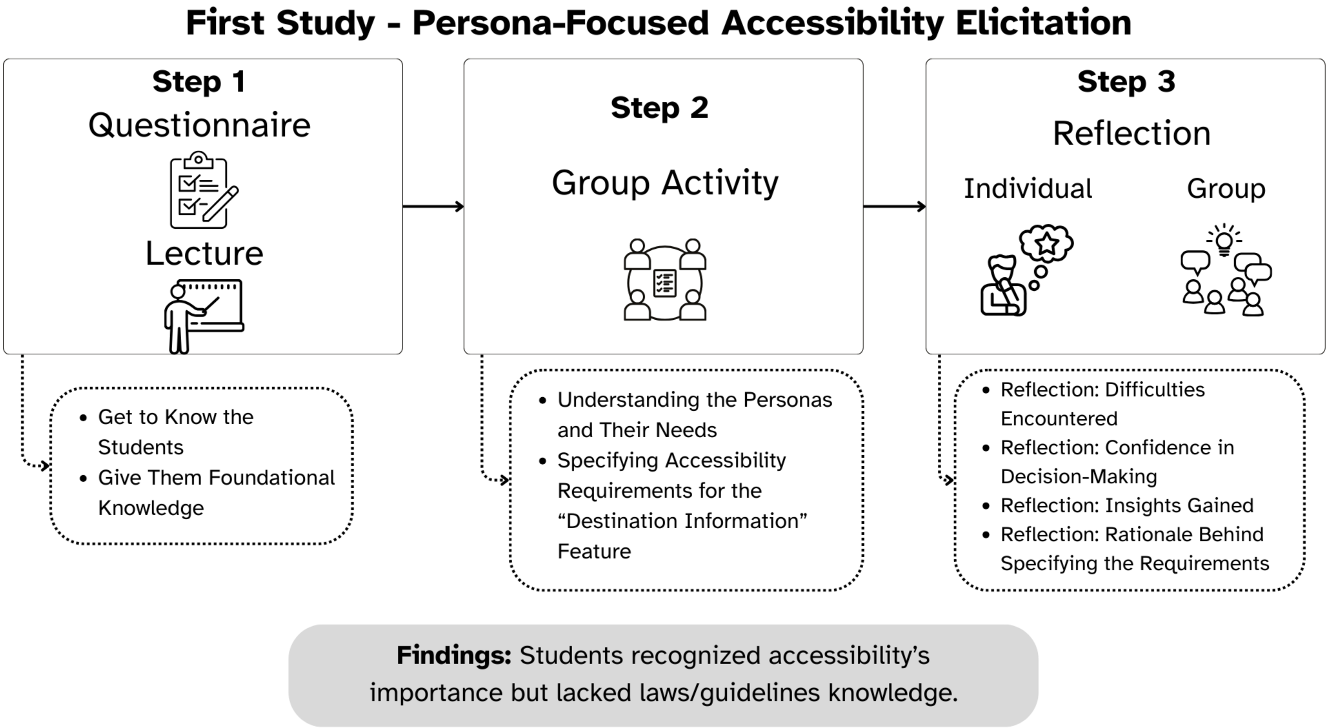

Figure 5. First Study Workflow

of accessibility concepts, including relevant laws and guidelines (e.g., WCAG), and familiarity with assistive technologies. Following this, a 30-minute lecture was delivered to provide foundational knowledge. The lecture addressed key topics such as the global and national prevalence of persons with disabilities, definitions and types of disabilities, and the concept of accessibility. It also highlighted the objectives of the United Nations' ENVision program to underscore the broader relevance of inclusive design. The session further introduced assistive technologies (e.g., VoiceOver, alternative keyboards, accessible fonts), the WCAG, and legal perspectives on accessibility across different countries.

Step 2 – Group Activity (Day 1: Collaborative Task): After the lecture, students were organized into small groups to engage in a practical activity focused on identifying accessibility requirements for the Destination Information feature. This functionality provided users with photos and descriptions of famous landmarks, recommendations for local activities, gastronomy and cultural highlights, and general travel tips.

Step 3 – Post-Activity (Day 2: Individual and Group Reflection): On the second day, the activity concluded with individual and group evaluations. Each student completed an individual questionnaire (Table 3) assessing their perceived difficulty in designing for the given personas, their confidence in the decisions made, and key insights gained from the experience. In parallel, groups collaboratively responded to a second questionnaire (Table 4), which explored their collective approach to accessibility. Questions examined whether students would have independently considered accessibility without explicit instructions, the relative complexity of designing for each persona, and the rationale and methods used to derive design requirements.

4.2 Data Collection and Analysis

To address our research questions comprehensively, we administered a pre- and post-activity questionnaire to capture both the baseline knowledge of students and their insights following the activity. The initial questionnaire was designed to evaluate participants' pre-existing familiarity with accessibility concepts, while the subsequent questionnaire assessed their confidence levels, encountered challenges, and overall experience in applying these concepts to practical scenarios. Additionally, a group discussion was conducted to elicit qualitative data regarding the students' decision-making processes, the rationale behind their choices, and their approach to incorporating accessibility requirements.

The combination of quantitative data from the questionnaires and qualitative insights from the discussion facilitated a comprehensive analysis of the effectiveness of the instructional methods, the depth of students' understanding of accessibility principles, and their capability to translate these principles into practical software design. This multifaceted approach enabled us to evaluate not only the theoretical knowledge but also the practical application of accessibility in software development, thereby providing critical insights into the efficacy of educational interventions and identifying potential areas for refinement in both teaching practices and software development methodologies.

4.3 Results

This section presents the findings from the First Study during the implementation of the learning activity, drawing on data collected through pre- and post-activity questionnaires administered to students individually and in groups. The analysis is structured into three phases, reflecting the design of

Table 2. Step 1 - Initial Questionnaire - Study 1

#	Question	Type
	Step - Initial Individual Questionnaire	
#	Question	Type
ID1	Name:	Open
ID2	Age:	Open
ID3	Course:	Open
ID4	Year and Semester of Entry:	Open
ID5	Are you currently interning or working in the field of IT?	Closed
	Questions about Accessibility	
Q1	Has the topic of Accessibility been addressed in any subject during your course?	Closed
Q2	If yes, in which subject?	Open
Q3	How familiar are you with laws (e.g., Brazilian Inclusion Law) and public policies that require accessibility in IT products, which ensure the right of people with disabilities to access information and communication?	Closed
Q4	How familiar are you with the guidelines of the Web Content Accessibility Guidelines (WCAG)? WCAG is a set of guidelines developed by the W3C to make web content more accessible to people with disabilities. The main goal is to ensure that websites and applications are usable by a wide range of users, including those with visual, auditory, motor, cognitive, and other disabilities.	Closed
Q5	How familiar are you with assistive technologies? Assistive technology refers to any device, equipment, software, or system designed to enhance the functionality and independence of people with disabilities. These technologies can be physical or digital and are developed to assist people with physical, cognitive, sensory, or communication disabilities. The goal of assistive technology is to reduce or eliminate barriers faced by people with disabilities, enabling them to perform daily tasks, participate in social activities, and access information more easily and effectively. (e.g., screen readers, adaptive keyboards and mice, voice recognition systems).	Closed

the intervention: initial assessment, individual and group reflections, and evaluation of the requirements produced.

4.3.1 Step 1 – Initial Self-Assessment

The initial questionnaire was completed by 53 students and aimed to gather demographic data and assess prior knowledge regarding accessibility. As shown in Table 5, 40% of respondents were 20 years old, and 98% were enrolled in the SE undergraduate program. A majority (62%) began their studies in the first semester of 2022, and 72% were currently employed or undertaking internships in the IT sector.

When asked whether accessibility had been addressed in their coursework, 58% of students responded affirmatively, 21% negatively, and 21% reported uncertainty. With regard to familiarity with accessibility-related laws and public policies, only 9% described themselves as moderately familiar; 34% were slightly familiar, and 57% reported no familiarity (Figure 6). A similar pattern emerged regarding the WCAG: only 4% of students indicated high familiarity, 8% moderate familiarity, 17% slight familiarity, and 71% reported being unfamiliar (Figure 7). Familiarity with assistive technologies (AT) was somewhat higher. Specifically, 49% reported being slightly familiar, 34% moderately familiar, only 4% very familiar, and 14% were unfamiliar (Figure 8).

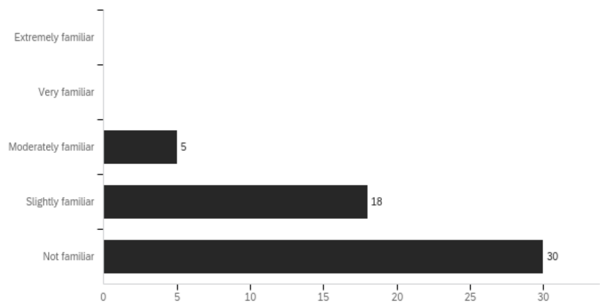

Figure 6. [Q3] Familiarity with Laws and Regulations

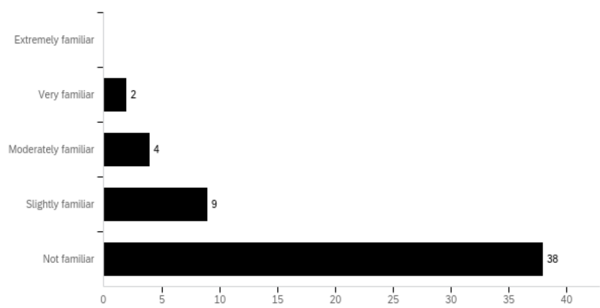

Figure 7. [Q4] Familiarity with WCAG

Table 3. Step 3 - Individual Questionnaire - Study 1

Step 3 - Final Individual Questionnaire		
#	Question	Type
	Scenario 1	
IQ1	What level of difficulty did you encounter in designing/eliciting the requirements for the functionality in scenario 1?	Closed
IQ2	What difficulties did you encounter?	Open
IQ3	How confident did you feel about making decisions on which functionality requirements should be included in scenario 1?	Closed
	Scenario 2	
IQ4	What level of difficulty did you encounter in designing/eliciting the requirements for the functionality in scenario 2?	Closed
IQ5	What difficulties did you encounter?	Open
IQ6	How confident did you feel about making decisions on which functionality requirements should be included in scenario 2?	Closed
	Final Questions About the Activity	
IQ7	Do you consider what you learned during your undergraduate course on accessibility useful for completing the task proposed during the activity?	Open
IQ8	If you had more time to perform the last class activity, what resources or materials would you seek for additional support to deepen your knowledge about accessibility?	Open
IQ9	After completing this activity, would you be inclined to explore more about accessibility?	Open
IQ10	How did this activity influence your understanding of the impact of accessibility in software development?	Open
IQ11	Considering the content and discussions addressed in this activity about accessibility in software development, would you be interested in a specific course that explored this topic in more depth?	Open
IQ12	Would you like to make any other observations about the topic?	Open
IQ13	Do you have any suggestions on how to improve the activity for future classes?	Open

Table 4. Step 3 - Group Questionnaire - Study 1

Step 3 - Group Questionnaire		
#	Question	Type
	Group Number:	Open
	Questions About the Activity	
GQ1	Considering the functionality presented and the personas with distinct needs that were provided, if it hadn't been explicitly mentioned that we needed to consider accessibility, would you have naturally thought about it during the requirement elicitation? Justify your answer.	Open
GQ2	Considering both scenarios, which one was more difficult to elicit requirements for, and why?	Open
GQ3	What rationale was used to identify the necessary requirements for each scenario? For example, we deduced by inference from the lay knowledge we have about the disability in one of the scenarios, we retrieved knowledge from a certain discipline and applied it to a specific scenario.	Open

Table 5. First Study - Participants Demographics

Category	Subcategory	Count	%
Age	19	2	4%
	20	21	40%
	21	11	21%
	22	6	11%
	23	3	6%
	24	2	4%
	25	4	8%
	27	1	2%
	32	1	2%
	34	1	2%
	41	1	2%
Major/Field of Study	Software Engineering	52	98%
	Systems Analysis and Development	1	2%
Year of Admission/Semester	2018/1	1	2%
	2018/2	1	2%
	2019	1	2%
	2019/2	1	2%
	2021/1	2	4%
	2021/2	4	8%
	2022/1	33	62%
	2022/2	9	17%
	2024/1	1	2%
Work or Does Internship In IT	Yes	38	72%
	No	15	28%

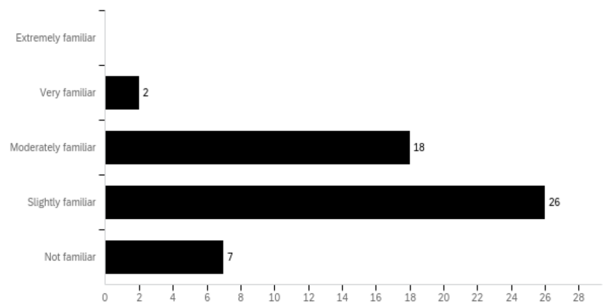

Figure 8. [Q5] Familiarity with Assistive Technologies

4.3.2 Step 2 – Evaluation of the Elicited Requirements

The requirements submitted by students during the design activity were analyzed for quality and relevance; although students were allowed to express them in free form, many adopted the structure provided in the instructional example.

It is important to note that the examples presented below were written by the students and are reproduced here verbatim to preserve the authenticity of their submissions. These examples reflect how participants initially conceptualized accessibility-related requirements in intuitive rather than technically structured terms. The majority of the requirements were generic and primarily focused on UX/UI aspects. Examples include: *“minimalist interface, initial indication of the Tab key, navigation fully guided by the Tab key”* [G4], *“minimalist and responsive interface”* [G6], *“simplified navigation, compatibility with VoiceOver, avoidance of overly long texts or instructions, simplified interface design, and clear separation of distinct topics”* [G5], and *“support for touch interaction”* [G9]. Several requirements were not explicitly related to accessibility and instead focused on general application functionality. These included: *“app tutorial”* [G7], *“quick access to recent searches”* [G5], *“travel recommendations based on search history”* [G1], *“preference filters”* [G6], and *“verbal communication with AI to assist with searches; algorithm that presents the best travel options for a pre-defined period in the app”* [G4]. These findings suggest that, although students actively engaged with the task, many faced challenges in translating accessibility principles into specific requirements.

4.3.3 Step 3 – Post-Activity Reflections – Individual Questionnaire

After completing the design task, students responded to a second individual questionnaire evaluating the perceived difficulty of the task, confidence in their decisions, and their overall learning experience.

Scenario 1 – Persona Maria. In the first scenario, students identified accessibility requirements for Maria, a 70-year-old user with arthritis and concentration difficulties. As shown in Figure 9, 39% of students rated the task as “neither easy nor difficult,” 34% as “partially easy,” and 11% as “extremely easy.” Only 18% found it partially difficult.

The difficulties described by students reflected three main themes (summarized below):

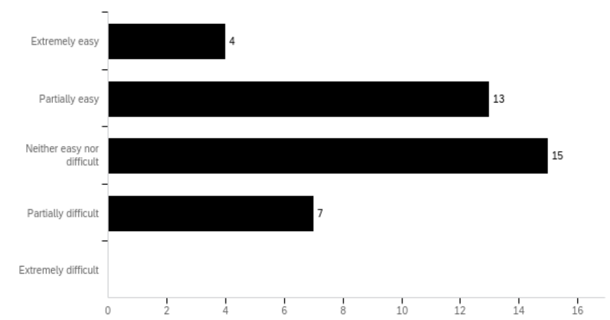

Figure 9. [IQ1] Difficulty in Eliciting Requirements for Scenario 1

1. Limited familiarity with the disabilities involved, making it difficult to propose targeted solutions (e.g., *”Understand exactly the problems caused by arthritis and how to solve them...”* [P35]; *”...little contact with people with this disability to understand their difficulties and needs.”* [P10]).
2. Complexity and tension in the persona characteristics, which some perceived as contradictory (e.g., *”...that the scenario involved a contradictory persona liking to read and having concentration issues.”* [P8]).
3. Challenges in generating non-generic or feasible solutions, including concerns about implementation or impact on other users (e.g., *”Not to think about functionalities that are too difficult to develop...”* [P11]; *”Mainly in creating new ideas, as the solutions are quite generic.”* [P38]; *”...how the solution found could negatively impact other users.”* [P35]).

Regarding confidence (Figure 10), most students reported feeling confident (59%), while 26% were neutral, 10% slightly confident, and only 5% very confident.

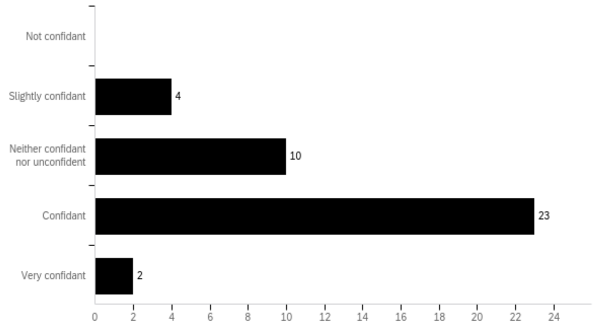

Figure 10. [IQ3] Confidence Level in Selecting Requirements for Scenario 1

Scenario 2 – Persona Lucas. The second scenario involved Lucas, a 32-year-old user with low vision who uses screen readers. Students reported this task as slightly easier than the first. As shown in Figure 11, 38% found it "partially easy," 21% "extremely easy," and 23% rated it "neither easy nor difficult." Only 18% found the task difficult to some extent.

Reported challenges for this scenario were similar to Scenario 1 and are summarized below:

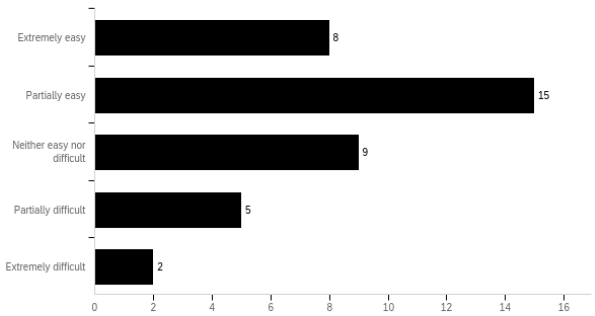

Figure 11. [IQ4] Difficulty in Eliciting Requirements for Scenario 2

1. Limited familiarity with the disability and assistive technologies (e.g., *"I have not had contact with people with low vision..."* [P23]).
2. Difficulty empathizing with the persona, particularly in imagining the user experience (e.g., *"...the main difficulty addressed is, first of all, putting oneself in the user's place..."* [P39]).
3. Struggling to propose new solutions, given overlap with ideas from the first scenario (e.g., *"...so it was hard to think of something new."* [P15]).

Additional comments involved challenges with AI-based solutions (e.g., *"...some solutions with artificial intelligence were necessary."* [P24]), the perceived severity of the condition (e.g., *"Because it is a more limiting condition, it is harder to understand how to meet their needs."* [P38]), coordinating decisions as a group (e.g., *"act as a group"* [P27]), defining scope (e.g., *"...the biggest difficulty is understanding the purpose."* [P42]), and adapting interfaces for screen readers (e.g., *"Finding ways to assist people who use screen readers..."* [P7]). Confidence levels (Figure 12) were lower in this scenario: 41% were neutral, 10% slightly confident, 5% very confident, and 3% reported feeling unconfident.

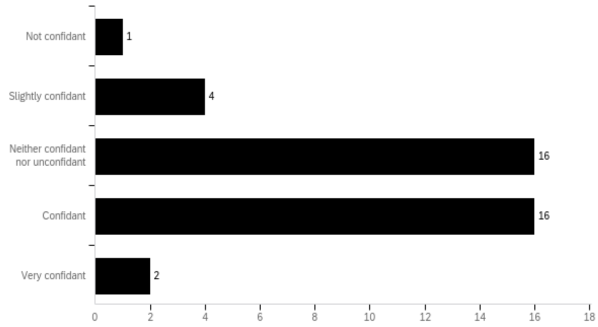

Figure 12. [IQ6] Confidence Level in Selecting Requirements for Scenario 2

4.3.4 Step 3 – Post-Activity Reflections – Group Questionnaire

Group responses shed light on the shared rationale behind participants' approaches, highlighted the obstacles they encountered, and provided insight into the strategies they used to reach consensus and make decisions.

[GQ 1] Considering the functionality presented and the personas with distinct needs that were provided, if it had not been explicitly mentioned that we needed to consider accessibility, would you have naturally thought about it during the requirement elicitation? Justify your answer. Through a detailed analysis, three core perspectives emerged:

- Lack of Spontaneous Consideration: Many groups admitted that accessibility would not have been addressed without explicit instruction (e.g., *"accessibility is not addressed in our day-to-day lives"* [G3]).
- Awareness Through Explicit Prompting: Some groups reported that explicit needs prompted broader consideration of diverse users (e.g., *"we had to do some research on the needs of the scenarios"* [G4]).
- Recognition of Difficulty in Addressing Diverse Needs: Some groups struggled to identify requirements for unfamiliar or less visible disabilities (e.g., *"we realized there are other needs beyond those we knew"* [G2]).

[GQ 2] Considering both scenarios, which one was more difficult to elicit requirements for, and why?

Most groups perceived Scenario 1 as more challenging, primarily due to the complexity of the disabilities involved. The key reasons included:

- Greater Complexity of Motor and Cognitive Needs: Some needs were seen as not fully solvable through software alone (e.g., *"motor needs do not depend solely on software"* [G3]).
- Lower Familiarity: Students reported limited exposure to arthritis and concentration-related difficulties (e.g., *"it is a specific case and requires greater attention"* [G6]).
- Need for Deeper Understanding: Concentration difficulties were seen as less visible and harder to interpret (e.g., *"we do not have as much knowledge about their needs"* [G11]).

[GQ 3] What rationale was used to identify the necessary requirements for each scenario? For example, did you draw inferences from lay knowledge about the disability in one of the scenarios, or apply knowledge from a particular discipline?

Students adopted a variety of approaches, combining everyday reasoning, previous coursework, and consultation of formal guidelines:

- Lay Knowledge and Everyday Experience: Requirements were sometimes based on general personal observations (e.g., *"we relied solely on our everyday experience..."* [G3]).
- Inference from Lay Knowledge: Many requirements emerged from intuitive reasoning rather than technical references (e.g., *"we made deductions by inference"* [G12]).
- Common Sense and Past Experiences: Some reasoning drew on UX-related course content (e.g., *"we used prior knowledge of accessibility tools in other contexts"* [G9]).
- Reference to Guidelines: Some groups applied W3C rules directly (e.g., *"using the rules defined by the W3C..."* [G8]).
- Academic and Technical Knowledge: Students referred to previous coursework in UX and requirements (e.g., *"through course modules such as UX..."* [G10]).
- Empathy and User-Centered Thinking: Several responses emphasized placing themselves in the persona's position (e.g., *"put ourselves in the persona's shoes"* [G6]).

These approaches illustrate how students navigated accessibility requirements using a mix of intuition, prior knowledge, and emerging conceptual understanding.

These approaches demonstrate a blend of theoretical knowledge, practical experience, and intuition in identifying the requirements for the described scenarios, underscoring the complexity and multidimensional nature of incorporating accessibility in software development.

4.4 Discussion

The findings of our study, when considered alongside the broader literature, suggest a gap between the recognized importance of accessibility in software development and the operational knowledge and practices among both practitioners and students (Lazar et al., 2004; El-Glaly, 2020; Patel et al., 2020; Bi et al., 2022; Vinadé and Marczak, 2024).

Paradox in Acknowledgment vs. Expertise: Previous work with Brazilian practitioners in 2024 (Vinadé and Marczak, 2024) points to a paradox in accessibility: while 80% of respondents acknowledged the value of accessibility for product quality, practical expertise remained variable. Specifically, 44% of practitioners rated their expertise in implementing accessibility features as partly or extremely insufficient, while only 27% considered it partly or extremely sufficient. This disparity underscores the need for improved training and application of accessibility practices. Similarly, students in our study described their knowledge as limited and reported that coverage in their courses was mostly superficial.

The same practitioner study (Vinadé and Marczak, 2024) identified several perceived barriers to integrating accessibility into projects. Many participants (75%) cited knowledge gaps, and 53% mentioned time constraints; additionally, nearly half found guidelines like WCAG difficult to apply. It remains an open question whether this is due primarily to the complexity of such guidelines or to other factors, such as limited exposure or resources. Students in our sample noted similar barriers related to both time and knowledge.

Educational Challenges Highlighted by Student Data: Our findings with students add further context to these issues. Many students in our projects turned to personal or practical knowledge when addressing accessibility requirements, rather than directly consulting guidelines or documentation. Main difficulties included innovating solutions, empathizing with people with disabilities, understanding user challenges, and making use of existing technical solutions. This tendency to emphasize individual experience over formal frameworks may reflect an area where accessibility education could be strengthened. Students often approached accessibility as a practical challenge, sometimes without a full appreciation of the underlying user needs or the theoretical basis for accessibility guidance.

Potential for Enhanced Educational Strategies: Our results are in line with previous research noting gaps in accessibility education. For example, Patel et al. (2020) showed that only 25% of surveyed practitioners had received substantial accessibility training in formal education. Similarly, Lazar et al. (2004) and Bi et al. (2022) identified limited coverage of accessibility topics during university studies. These data underscore potential benefits if institutions were to integrate dedicated accessibility modules, case-based workshops, or collaborative project experiences. Practice-oriented approaches, such as those advocated by El-Glaly (2020), appear promising for bridging the gap between conceptual understanding and implementation.

Bridging the Gap Between Theory and Practice: Based on these findings, we suggest that a more comprehensive strategy may be helpful for closing accessibility gaps in software development. Integrating accessibility as a core subject within curricula and promoting direct collaboration with experts or people with disabilities may offer students more practical insight and empathy. Supplementing traditional coursework with online modules or self-paced resources may further support practitioners in keeping current with evolving standards. As noted by Kawas et al. (2019), short, focused modules can help educators incorporate accessibility in ways that suit a variety of courses and contexts.

While many recognize the importance of accessibility for product quality, our data suggests that knowledge and consistent practice are not yet widespread. Progress in accessibility in software development may benefit from enhanced curricular strategies, expanded training, and continued re-emphasis of accessibility as a fundamental quality attribute. Such efforts could increase availability of inclusive and accessible technology, better addressing the needs of a diverse user base.

Improving the effectiveness of accessibility in practice may also depend on integrating these considerations earlier in the development cycle—through accessibility assessment, architectural design, iterative review, and systematic testing. Yet, as our first study indicates, this ideal is seldom fully realized in education or industry at present. While there is broad agreement on the importance of accessibility, both professionals and students frequently express uncertainty about how or where to begin. Building on this, our second study explores how methodologies like Behavior-Driven Development and reference to formal guidelines (WCAG) could help make inclusive design decisions a more foundational aspect of engineering work.

5 Second Study

This second study investigates how undergraduate Software Engineering students (Table 11) incorporate accessibility requirements into the specification of system functionalities when supported by BDD scenarios. This study involved a student group different from the first, as previously noted. The study focuses on how students integrate WCAG into system behavior specifications using BDD scenarios. It aims to assess participants' baseline knowledge of accessibility (RQ1), evaluate their ability to apply accessibility principles using User Stories and BDD (RQ2), and examine the impact of instructional interventions on the quality and clarity of the requirements produced. The same TravelMate system and interface used in the first study are adopted here; however, the tasks were more structured.

Students were asked to formalize accessibility-related requirements based on predefined personas. Their performance was tracked across sessions, enabling the analysis of how their understanding evolved and which challenges they encountered when applying accessibility standards in realistic scenarios. Demographic and baseline data were collected through pre-activity questionnaires, which also included self-assessment of familiarity with BDD, accessibility concepts, and WCAG. The analysis of deliverables generated throughout the study helped identify recurring patterns and learning gaps, contributing to a deeper understanding of how structured instructional strategies support SE students in specifying accessibility as a non-functional requirement.

5.1 Activity Design and Implementation

The activity was structured around three consecutive class sessions (on different days), combining theoretical content, hands-on practice, and structured reflection. Activities were designed to simulate real-world software development tasks, particularly the requirements elicitation process, while emphasizing accessibility as a non-functional requirement (Figure 13). Emphasis was placed on how BDD can support formalization and collaboration when articulating accessibility requirements. Through these exercises, participants used BDD to guide the specification of accessibility requirements. By analyzing a proposed application, its personas, and WCAG principles, they wrote non-functional requirements in the "Given-When-Then" format, aligning functionalities with user needs and accessibility standards

Step 1—Baseline Self-Assessment and Initial Activity: Participants completed a pre-activity questionnaire aimed at assessing their familiarity with accessibility concepts, BDD, assistive technologies, and related legal frameworks. New questions were added to this questionnaire, as shown in Table 6. Following this, they were introduced to a fictional travel app, TravelMate, and tasked with identifying and documenting accessibility requirements for the "Destination Information" feature. This was done using US and BDD scenarios. At this stage, participants had not received formal instruction on accessibility standards such as WCAG.

Step 2—Instructional Intervention and Reflection: A 60-minute lecture was delivered, introducing accessibility-related laws and policies, as well as the WCAG. The lecture was organized around WCAG's four foundational principles (Perceivable, Operable, Understandable, and Robust) and included examples of applying these principles with BDD. Topics included keyboard navigation, screen reader support, color contrast, and inclusive interaction design. After the lecture, participants completed a revised questionnaire (see Table 7) focused on their experience in requirements elicitation, perceived challenges, and their understanding of accessibility.

Step 3—Application of WCAG with BDD: Participants completed a second specification activity, analyzing a commercial application, specifically its "Must-See Experience" feature, to identify and document accessibility requirements. Drawing on the accessibility concepts presented during the lecture and using a simplified version of the WCAG guidelines[1] Two additional questionnaires were administered: an individual questionnaire focused on participants' experiences using WCAG and BDD (see Table 8), and a group questionnaire (see Table 9) exploring decision-making strategies and process reflections. This three-day activity promoted progressive engagement with accessibility. Hands-on components gave participants the chance to apply principles in concrete scenarios, while instructional segments aimed to bridge theoretical knowledge and practical implementation.

5.2 Data Collection and Analysis

The second study followed a mixed-methods approach, combining quantitative and qualitative data to assess the instructional intervention and participants' engagement with accessibility requirements. Quantitative data were obtained through Likert-scale items in pre- and post-activity questionnaires. Descriptive statistics were used to analyze self-reported familiarity, confidence, and perceived difficulty. Qualitative data were derived from written artifacts (User Stories and BDD scenarios) produced during Step 1 and Step 3. A two-step analysis was conducted on both sets of artifacts:

1) Quality Evaluation: Each artifact (i.e., the combination of a User Story and its associated BDD scenarios) was as-

[1] The participants used a simplified version of WCAG available at `https://guia-wcag.com/`. Participants first explored the application and examined how the selected feature functioned. They then identified which WCAG principles were relevant to that functionality and used User Stories and BDD scenarios to specify the expected accessibility-related behavior of the system, following the structured formats introduced during the instructional sessions.

Table 6. Step 1 - Initial Questionnaire - Study 2

Step 1 - Initial Questionnaire		
#	Question	Type
ID6	Do you know someone with a disability? ★	Closed
ID7	Do you use or have you ever used the Behavior-Driven Development (BDD) technique? ★	Closed
	Questions about Accessibility	
Q3	How would you rate your knowledge and skills in accessibility? ★	Closed

★$Notincludedintheinitialiteration, butaddedinthisone.$

Table 7. Step 2 - Individual Questionnaire - Study 2

Step 2 - Individual Questionnaire		
#	Question	Type
ID1	Name: ★	Open
ID2	Student ID number: ★	Open
	Final Questions About Accessibility	
IQ1	During the activity, what level of difficulty did you encounter in designing/eliciting the requirements for the personas? ★	Closed
IQ2	During the activity, what level of difficulty did you encounter in designing/eliciting the requirements for the personas? ★	Open
IQ3	During the activity, how confident did you feel when making decisions about which functionality requirements should be included for the personas? ★	Closed
	Final Questions About the Activity	
IQ4	Do you consider what you learned during your undergraduate course on accessibility useful for completing the task proposed during the activity? Explain.	Open
IQ5	After the activity, do you feel more capable of clearly describing the adaptations the system needs to accommodate users with accessibility needs? Explain.	Open
IQ6	How did this activity influence your understanding of the impact of accessibility in software development?	Open
IQ7	Considering the content and discussions addressed in this activity about accessibility in software development, would you be interested in a specific (optional) course or mini course that explored this topic in more depth? ★	Open
IQ8	Do you have any suggestions on how to improve the activity for future activities?	Open

★$Newquestion.Inthisiteration, somequestionswereremoved.$

Table 8. Step 3 - WCAG with BDD Questionnaire - Study 2

Step 3 - WCAG with BDD Questionnaire ★		
#	Question	Type
ID1	Name:	Open
ID2	Student ID number:	Open
	Final Questions about the Use of WCAG and BDD	
IQ1	The WCAG guidelines were easy to understand.	Closed
IQ2	It was easy to identify which WCAG guidelines were relevant to each project requirement.	Closed
IQ3	The WCAG helped to consider accessibility aspects that were not addressed in the original version.	Closed
IQ4	How easy was it to use the WCAG guidelines to describe User Stories and specify BDD scenarios?	Closed

★$Newquestionnaire.$

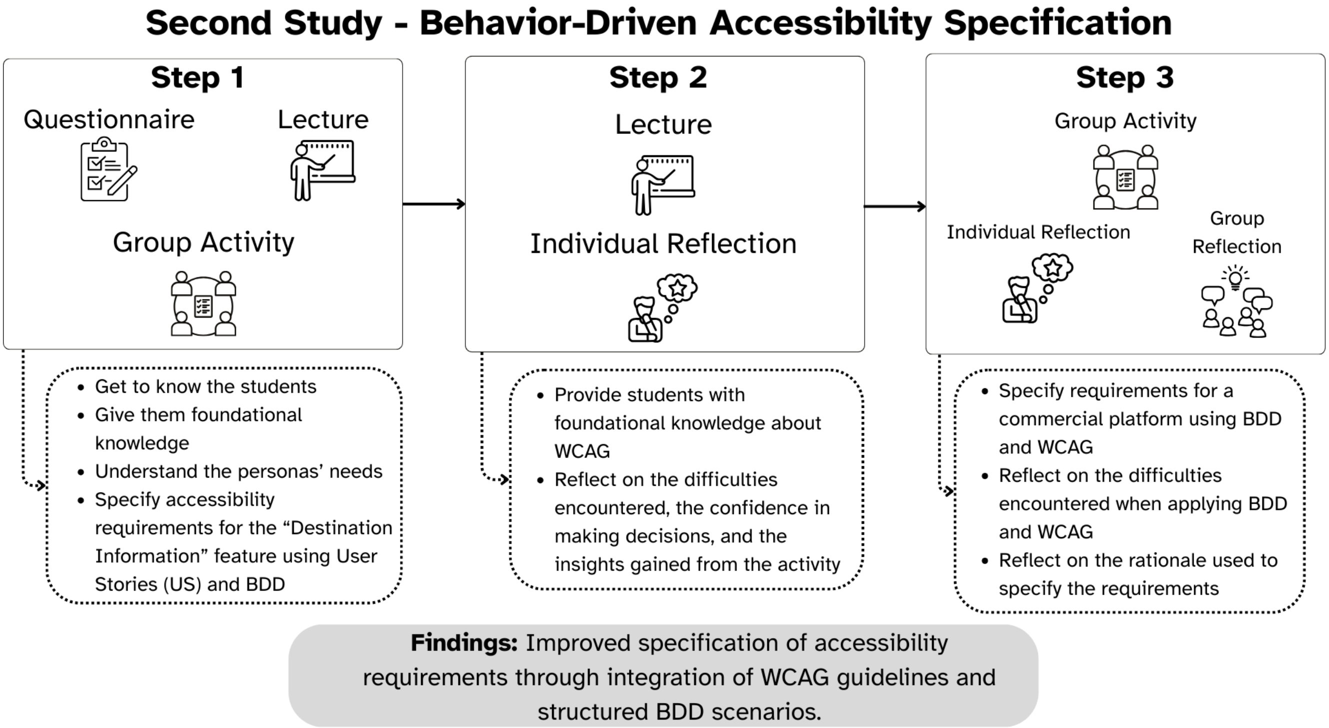

Figure 13. Second Study Workflow

Table 9. Step 3 - Group Questionnaire - Study 2

#	Question	Type
	Step 3 - Group Questionnaire	
	Questions About the Activity	
GQ2	Considering the two personas, for which one was it more difficult to elicit the requirements and write the BDD scenarios? Why? ★	Open
GQ3	What rationale did you use to identify the requirements and BDD scenarios for each persona? For example, did you infer from your general understanding of one persona's disability, or did you apply knowledge from a specific course subject when writing the requirements? ★	Open

★$New question.$

sessed using three predefined evaluation criteria (see Table 10): (i) identification of personas' needs; (ii) use of WCAG concepts and guidelines; and (iii) clarity and quality of specification. Each criterion was rated on a four-level scale: Advanced, Intermediate, Basic, or Unsatisfactory. Two researchers independently assigned ratings to each artifact per criterion. A reconciliation meeting resolved discrepancies and established consensus. The third author reviewed the finalized categorizations to validate the evaluation and minimize bias.

2) Profile Categorization: After evaluation, all groups' results from both specification tasks were compared. Patterns of change were analyzed across the three criteria. Groups demonstrating similar progress or stagnation were clustered together, resulting in three performance profiles:

- Profile 1—Consistent: Groups whose artifacts reflected strong alignment with accessibility principles and maintained high quality after instruction;
- Profile 2—Significant Evolution: Groups that demonstrated marked improvement in quality and WCAG alignment after instruction;
- Profile 3—Little Progress: Groups whose artifacts remained vague or misaligned with accessibility goals despite instruction.

This categorization provided a clearer understanding of the intervention's impact and differing levels of assimilation.

5.3 Results

5.3.1 Step 1 – Baseline Knowledge and First Specification Task

In this second study, data were collected from 60 young professionals. The information gathered included demographic details, age, and professional background, such as academic and work experience, in order to assess their initial knowledge of accessibility. Additional questions were incorporated to explore whether participants knew someone with a disability and whether they had prior experience with BDD.

Table 10. Evaluation Criteria

Criterion	Advanced	Intermediate	Basic	Unsatisfactory
Identification of personas' needs	Clearly identified all difficulties and needs of the proposed personas.	Identified most of the personas' difficulties with minor flaws.	Identified few difficulties of the personas.	Was not able to adequately identify the personas' needs.
Use of concepts and guidelines (WCAG)	Demonstrated clear mastery of WCAG guidelines (colors, keyboard, error prevention, etc.).	Used WCAG concepts well with minor conceptual errors.	Used WCAG concepts superficially.	Did not use or used WCAG concepts incorrectly.
Clarity and quality of presentation	Clear, structured, and objective presentation.	Good presentation, with minor clarity or structure issues.	Poor or slightly structured presentation, confusing in some points.	Disorganized presentation and not very understandable.

Table 11. Second Study - Participants Demographics

Category	Subcategory	Count	%
Age	19	5	8%
	20	30	50%
	21	8	13%
	22	4	7%
	23	6	10%
	24	4	7%
	25	2	3%
	46	1	2%
Major/Field of Study	Software Engineering	60	100%
Year of Admission/Semester	2020/2	1	2%
	2021/1	2	3%
	2021/2	1	2%
	2022/1	6	10%
	2022/2	5	8%
	2023/1	43	72%
	2023/2	2	3%
Work or Does Internship In IT	Yes	51	85%
	No	9	15%

Among the participants, 50% were 20 years old (see Table 11). All were undergraduate participants in Software Engineering, and 72% had begun their studies in the first semester of 2023. At the time of data collection, 85% of participants were either employed or engaged in internships in the IT field.

When asked whether they personally knew someone with a disability, 70% of participants responded affirmatively. Regarding their familiarity with BDD, 63% had encountered it in their coursework, while 7% had used it in a professional setting. An additional 15% were familiar with the concept but had not used it, and 18% had neither heard of nor used BDD.

Participants were also asked whether accessibility had been addressed during their undergraduate courses: 50% answered yes, 27% said no, and 23% were unsure. Among those who answered affirmatively, accessibility was most commonly discussed within User Experience and Requirements Engineering. When participants were asked to rate their own knowledge and skills in accessibility, responses varied: 35% felt their skills were neither sufficient nor insufficient, another 32% described their skills as partially sufficient, and 33% considered their skills to be partially or extremely insufficient (Figure 14). Regarding familiarity with accessibility laws and public policies, 17% of participants reported moderate familiarity, 27% indicated slight familiarity, and 56% reported being unfamiliar (Figure 15). A similar pattern emerged in responses related to WCAG: 8% were moderately familiar, while the majority were either slightly familiar (32%) or unfamiliar (60%) (Figure 16). In terms of familiarity with assistive technologies, 40% reported moderate familiarity, 32% slight familiarity, 5% were very familiar, and 23% were unfamiliar (Figure 17).

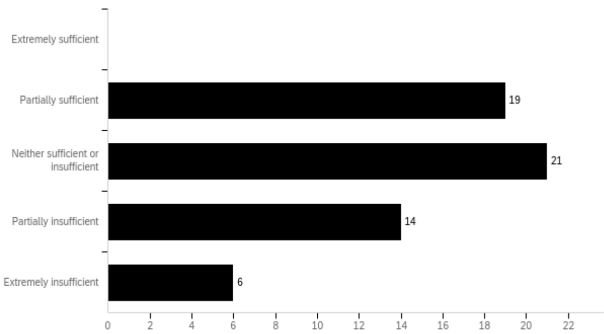

Figure 14. [Q3] Self-rated Knowledge and Skills in Accessibility

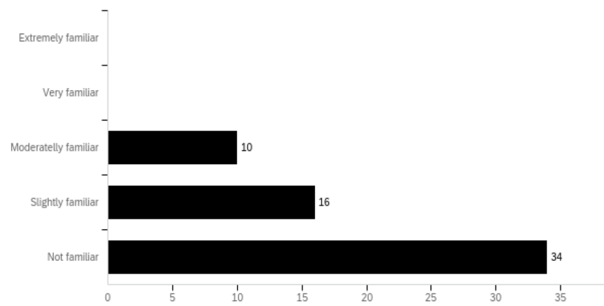

Figure 15. [Q4] Familiarity with Laws and Regulations

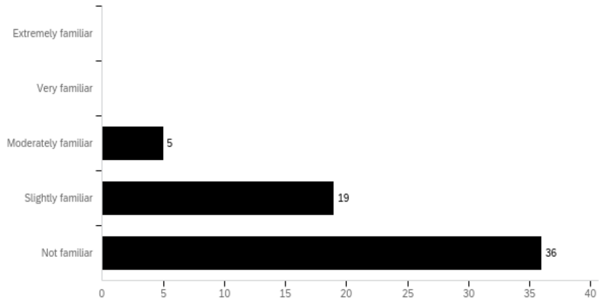

Figure 16. [Q5] Familiarity with WCAG

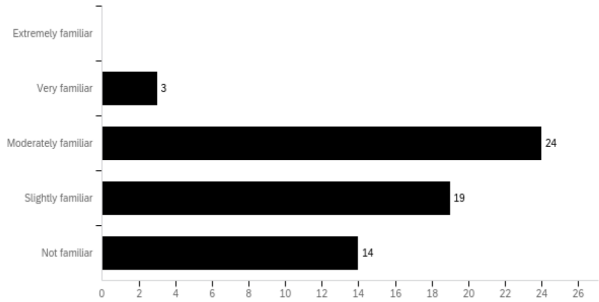

Figure 17. [Q6] Familiarity with Assistive Technologies

5.3.2 Review of the Specified Requirements Focusing on Syntax Usage

This phase focused solely on evaluating whether participants could express accessibility requirements using the US and BDD formats; the quality of the requirements was not assessed. During the first activity centered on writing non-functional accessibility requirements, seven out of ten groups successfully structured their requirements using both formats. These groups demonstrated an initial understanding of the needs of personas with disabilities and incorporated basic accessibility elements. Generally, the User Stories were somewhat generic, while the BDD scenarios displayed a higher level of detail. Nonetheless, most submissions lacked specific acceptance criteria, limiting their testability. Figure 18 illustrates an example of a User Story and its corresponding BDD scenario submitted by one group, which showcases their approach to documenting accessibility requirements.

User Story

As an elderly user or a user with low vision,
I want to be able to adjust the font and icon sizes in the application,
So that I can interact with the software more comfortably.

BDD Scenario

Given that the accessibility mode for visual impairments is enabled,
When I click on a component or hover over it with the cursor,
Then the content of the component should be described.

Figure 18. [First Day] Specifying Requirements Using US and BDD

Although most groups attempted to describe accessible functionalities, many found it difficult to structure accessibility-related components effectively, revealing gaps in their understanding of the personas' needs and system interactions. Some groups also struggled to maintain coherence between the User Stories and corresponding BDD scenarios, compromising the consistency of their specifications.

In contrast, three groups were unable to complete the activity satisfactorily. Issues included failure to propose relevant functionalities for the application, replication of the example provided during the lecture without adaptation, and a lack of alignment between the functionalities, personas, and key accessibility considerations.

5.3.3 Step 2 – Perceptions After the First BDD Practical Activity

After completing the activity on US and BDD scenarios for identifying accessibility requirements related to the "Destination Information" feature of the fictional app *TravelMate*, a second questionnaire was administered. This time, 50 of the 60 participants responded. The questionnaire aimed to explore participants' perceptions of the difficulty of eliciting and designing accessibility requirements. Unlike on the first day, this round of questions did not differentiate between personas. Participants were asked to reflect on the ease of writing US and BDD scenarios, describe the challenges they encountered, and assess their confidence in selecting appropriate accessibility features. Additional questions examined how useful their undergraduate accessibility training was in completing the activity and how the experience shaped their views on accessibility in software development.

When asked about their familiarity with writing User Stories, 88% of participants reported feeling extremely, very, or moderately familiar. Only 2% indicated unfamiliarity, and 10% reported slight familiarity (Figure 19). Regarding familiarity with specifying BDD scenarios, 60% were very or moderately familiar, 6% extremely familiar, 26% had slight familiarity, and 8% were extremely unfamiliar (Figure 20). When asked whether writing User Stories based on the provided personas was easy, 84% strongly or somewhat agreed, 12% were neutral, and 4% somewhat disagreed (Figure 21).

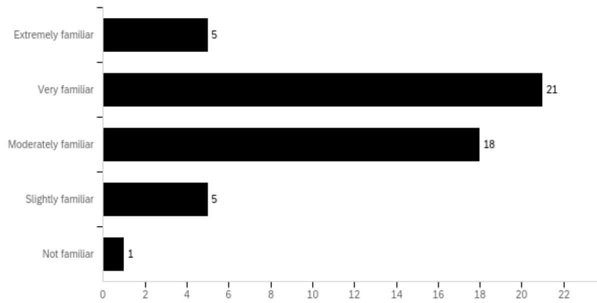

Figure 19. Familiarity with writing User Stories

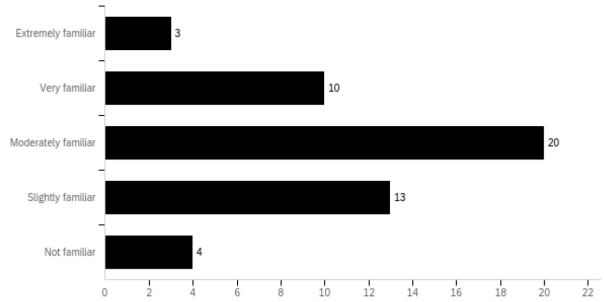

Figure 20. Familiarity with specifying BDD scenarios

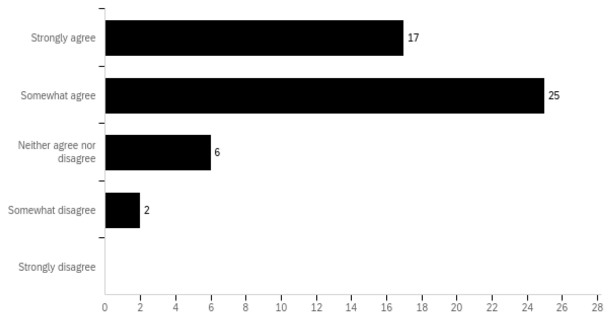

Figure 21. Writing the User Stories based on the given personas was easy.

A similar trend appeared regarding BDD scenarios: 60% agreed it was easy to specify them for accessibility-related features, 32% were neutral, and 8% somewhat disagreed (Figure 22). In terms of learning outcomes, 56% of participants strongly agreed that the activity helped them understand how to integrate users with disabilities into system functionalities, and 40% somewhat agreed. Only 4% were neutral (Figure 23).

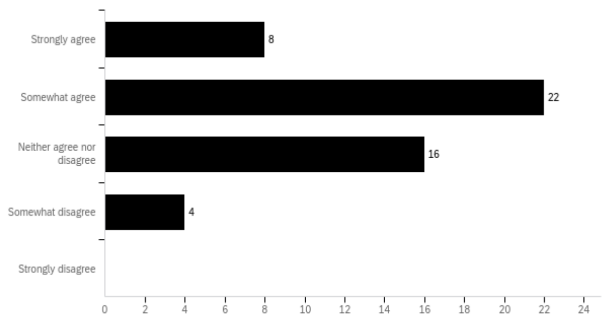

Figure 22. Specifying BDD scenarios for accessibility-related functionality was easy.

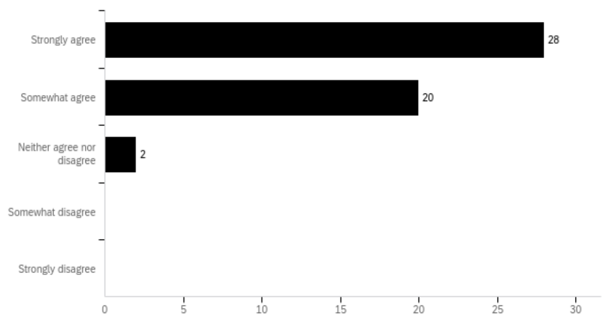

Figure 23. The activity helped me better understand how to integrate the user with a disability into the system's functionality.

Regarding the overall difficulty of the task, most participants felt it was slightly easy, while 26% rated it as neither easy nor difficult. A few (8%) found it somewhat difficult, and only 4% considered it extremely easy. The main challenges reported included difficulty empathizing with the personas and a lack of creativity. Participants also cited limited knowledge and experience with accessibility concepts as barriers. When asked about their confidence in deciding which accessibility features to include (Figure 24), 44% felt neutral, 20% were not very confident, 34% felt confident, and 2% were very confident. Most participants felt that their undergraduate coursework had not sufficiently prepared them for this task, noting that accessibility content was either too superficial or entirely absent. Finally, many participants reported that the activity changed their perception of accessibility in software development. They began to recognize its importance and the significant impact it has on the lives of people with disabilities. Some participants also expressed surprise that accessibility is a legal requirement in many contexts.

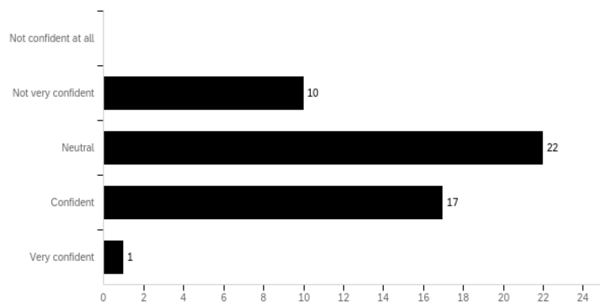

Figure 24. Confidence designing or eliciting requirements for the personas during the activity.

5.3.4 Step 3 – Specifying with BDD and WCAG: Second Practical Activity

On the final day of the study, after completing the second specification activity, participants analyzed a commercial platform and identified accessibility requirements for its "Must-See Experience" feature. They then completed two final questionnaires: an individual questionnaire (answered by 58 participants), which focused on the use of WCAG and BDD, and a group questionnaire that explored their rationale and decision-making process. Participants generally reported that the WCAG guidelines were understandable: 52% strongly agreed, 41% somewhat agreed, and 7% were neutral. Similarly, most participants (81%) agreed that WCAG helped them consider aspects of accessibility that had been overlooked. Regarding the use of WCAG in writing User Stories and BDD scenarios, 55% found this somewhat easy, 24% extremely easy, 17% were neutral, and only 2% reported difficulty.

[GQ1] Considering the functionality presented and the personas with distinct needs that were provided, if it had not been explicitly mentioned that you needed to consider accessibility, would you have naturally thought about it during the requirement elicitation? Justify your answer.

Three main perspectives emerged:

- Lack of Spontaneous Consideration: Accessibility was generally not considered unless explicitly required (e.g., *"We wouldn't have considered accessibility from the beginning."* [G3]).
- Limited Awareness or Exposure: Participants rarely thought about accessibility in daily contexts (e.g., *"It's not something we're used to doing."* [G2]).
- Importance of Explicit Inclusion: Accessibility was addressed only when persona needs made it necessary (e.g., *"We would naturally consider it because the personas required it."* [G8]).

[GQ2] Considering the two personas, which one was more difficult to elicit requirements and write BDD scenarios for? Why?

Most groups found **Maria** more challenging due to:

- Intersecting Motor and Cognitive Needs: Solutions felt less clear or intuitive (e.g., *"Her impairments are more specific and solutions are less common."* [G3]).
- Lower Familiarity: Students were less familiar with arthritis and concentration-related challenges (e.g., *"It was not easy to identify limitations related to both motor and cognitive conditions."* [G5]).

[GQ3] What rationale did you use to identify the requirements and BDD scenarios for each persona?

Students described using a combination of approaches:

- Lay Reasoning and Common Sense: Inference based on general understanding of disabilities (e.g., *"We made inferences based on our lay knowledge."* [G2]).
- Reference to Accessibility Guidelines: Including WCAG and legal frameworks.
- Course-Based Knowledge: Drawing on concepts introduced during lectures and previous coursework.

5.3.5 Inspection of the Specified Requirements According to the Listed Evaluation Criteria

The analysis was conducted in three stages. First, the specifications produced in the initial activity (before the accessibility lecture) and in the second activity (after the introduction of WCAG) were evaluated. In both cases, User Stories and BDD scenarios were assessed according to the criteria presented in Table 10. Next, we compared the results across the two moments to identify changes in how accessibility principles were interpreted and incorporated into the specifications. Finally, groups demonstrating similar patterns of progress or stagnation were clustered into performance profiles, representing different learning trajectories observed during the study.

- **Profile 1 – Consistent (2 groups):** These groups demonstrated an initial understanding of accessibility and maintained the quality of their specifications across both activities. Although the overall structure of the requirements did not change substantially, terminology became more precise and more closely aligned with WCAG.
- **Profile 2 – Significant Evolution (5 groups):** These groups initially produced vague and incomplete User Stories and BDD scenarios with limited alignment to accessibility principles. After the lecture, however, they presented requirements that were clearer, more specific, and more consistently guided by WCAG, suggesting a meaningful incorporation of the concepts discussed.
- **Profile 3 – Little Progress (3 groups):** These groups showed minimal improvement. Specifications remained generic, lacking clarity and alignment with accessibility criteria. Even after instruction, the scenarios did not sufficiently describe system behavior in a way that addressed the personas' accessibility needs.

> This categorization highlights how instructional support influenced the quality of the accessibility requirements and illustrates persistent challenges in assimilating and applying accessibility concepts.

Profile 1 – Consistent: The groups classified in Profile 1 had already demonstrated an understanding of accessibility in the first activity, even before the introduction of the WCAG guidelines. Their initial User Stories (US) were generally consistent with accessibility concepts, although somewhat generic. The strongest evidence of this understanding appeared in the BDD scenarios, where participants more explicitly specified system behavior to address the needs of users with disabilities. Thus, even without direct guidance from WCAG, these groups were able to incorporate accessibility considerations into their requirements. After the WCAG lecture and the second specification activity, these groups largely maintained the same structure and approach; however, their terminology became more precise and aligned with WCAG. The specifications also began to articulate the expected system behavior in a more technical manner. As illustrated in Figure 25, the initial specifications already reflected accessibility principles, though at a basic level. Initially, the requirements mainly addressed motor precision issues (e.g., increasing button size). In the second activity, the specifications expanded to consider both motor and concentration-related challenges, resulting in more comprehensive and inclusive requirements. The second specification also incorporated normative accessibility aspects more explicitly. Moreover, the BDD scenarios became clearer and more operational, offering a more concrete description of how accessibility should be implemented in the system.

Before WCAG:

Given that I have difficulty with click precision,
When there are pop-ups, ads, or buttons,
Then there should be an option to disable/close them with a button that has a larger clickable area.

After WCAG:

Given that I am a person with mobility impairments and/or difficulty concentrating,
When I access the detailed information section about the website experience,
Then the site displays clear, concise, and complete information with a simple design, featuring adjustable fonts and buttons with a larger clickable area, organized into specific categories.

Figure 25. [Analysis] Profile 1 - Consistent

Profile 2 – Significant Evolution: Groups in Profile 2 initially presented generic or incomplete User Stories and BDD scenarios, with limited reference to accessibility and unclear descriptions of system behavior. The lack of familiarity with accessibility criteria made it difficult for them to articulate solutions tailored to diverse user needs. After the introduction of the WCAG guidelines, however, these groups showed clear improvement: scenarios became more detailed, structured, and aligned with the personas' needs. User Stories and BDD scenarios incorporated more explicit accessibility elements, such as screen reader support, contrast adjustment, and font customization. This progression reflects a more consistent understanding of inclusive design and a better ability to translate guidelines into actionable requirements. As shown in Figure 26, the specifications evolved from broad and generic descriptions to more precise and WCAG-aligned scenarios.

Table 12. Comparison of accessibility requirement specification practices in Study 1 and Study 2.

Element Compared	Study 1 (Unstructured approach)	Study 2 (Structured approach with Personas, WCAG, US, and BDD)
How participants decided what to specify	Decisions were based on general interpretations of personas and everyday assumptions about making the interface "easier to use."	Decisions were informed by the specific needs of the personas and explicitly connected to WCAG criteria presented during the instructional activity.
How requirements were written	Requirements were expressed in broad or general terms (e.g., "simplified interface," "easy navigation," "screen reader compatibility").	Requirements were structured as *User Stories*, specifying who needs the functionality, what is needed, and for which purpose.
How the expected system behavior was described	The expected behavior remained implicit or loosely defined.	Behavior was described using *BDD* scenarios (Given–When–Then), making actions and expected outcomes explicit and observable.
Verification of the requirement	The lack of detail hindered the evaluation of whether accessibility needs were actually addressed.	*BDD* scenarios enabled verification by providing observable conditions to assess whether the requirement was met.
Role of accessibility in the specification	Treated primarily as an interface-level adjustment or simplification.	Treated as an integrated aspect of the functional requirement from the beginning of the specification process.

Before WCAG:

Given that Lucas accesses the app,
When he activates the screen reader,
Then all information should be narrated correctly.

After WCAG:

Given that I am a visually impaired person planning to travel to Porto Alegre,
When I access the detailed information section about a specific experience,
Then the system should display the information ensuring that all content is compatible with the screen reader, with a proper structure for audio description of the presented sections,
And there should be an option to adjust contrast and font size,
And videos and texts should have appropriate audio descriptions.

Figure 26. [Analysis] Profile 2 - Significant Evolution

Profile 3 – Little Progress. The groups classified in Profile 3 demonstrated persistent difficulties in specifying User Stories and BDD scenarios, both before and after the introduction of the WCAG guidelines. Their requirements were generally vague, incomplete, and not clearly aligned with accessibility needs. Challenges included limited understanding of accessibility concepts and persona needs, difficulty defining expected system behavior, and the absence of concrete non-functional requirements. Although these groups were able to recognize WCAG criteria in theory, this knowledge did not translate into more precise or actionable specifications, suggesting that instruction alone was insufficient without deeper engagement in the activity. As illustrated in Figure 27, even when accessibility was mentioned (e.g., low vision), descriptions lacked detail and did not result in adaptations to the User Stories or BDD scenarios, which remained broad and difficult to validate. These findings indicate that some learners may require additional scaffolding, guided modeling, or more structured collaboration to meaningfully internalize accessibility during requirements elicitation.

Before WCAG:

As a user,
I want a simple application,
So that I can use it without complications.

After WCAG:

As a person with low vision,
I want the texts to follow WCAG standards,
So that the screen reader can read the information on the screen.

Figure 27. [Analysis] Profile 3 - Little progress

5.4 Discussion

The results of the second study indicate the potential effectiveness of integrating **Personas**, **User Stories (US)**,

Behavior-Driven Development (BDD), and **WCAG** as a combined approach to embedding accessibility considerations into requirements elicitation. While prior studies such as Shirogane (2014); Oliveira et al. (2016); Miranda (2021) propose methods for incorporating accessibility during the requirements phase, these typically rely on profile-based approaches, formal modeling, or tool-centric workflows. Likewise, works such as Akoumianakis (2009); Miranda et al. (2024) employ domain-specific modeling techniques to represent accessibility constraints. However, to our knowledge, few approaches combine accessibility principles with Personas, US, BDD, and WCAG in a way that is explicitly empathy-driven. Our findings suggest that linking realistic personas with structured specification formats can support students in translating abstract accessibility principles into concrete system behaviors particularly in early-stage agile contexts. This is aligned with Putnam et al. (2015), who emphasize the importance of empathy-building in accessibility education, as well as El-Glaly (2020), who advocate for integrating accessibility as a foundational, rather than peripheral, topic throughout computing curricula. Progress across the three-day intervention showed that, although many participants had limited prior familiarity with accessibility, explicit instruction and guided practice enabled meaningful engagement.

In particular, groups in **Profile 2** demonstrated clear improvement in the clarity and WCAG alignment of their specifications after instruction, suggesting that structured scaffolding can effectively support the transition from intuitive reasoning to explicit requirement articulation.

Conversely, groups in **Profile 3** showed limited progress, even after the instructional intervention. These cases point to the need for differentiated instructional strategies that address varying levels of prior knowledge, familiarity with accessibility tools, and classroom engagement. This finding mirrors the first study, where accessibility considerations were often not raised spontaneously unless explicitly prompted. Awareness alone therefore appears insufficient; sustained exposure, repetition, and deliberate reflection may be necessary for accessibility to become internalized practice. Additionally, while most participants reported familiarity with US and BDD formats, several struggled to empathize with the personas, particularly when disabilities were unfamiliar or less visible. This difficulty likely influenced the specificity and relevance of the requirements produced. These results highlight the importance of instructional designs that support not only the technical structure of requirements but also the cognitive and reflective processes involved in recognizing diverse user needs.

Contribution. The integration of Personas, User Stories, BDD, and WCAG helped students move from intuition-based reasoning to the specification of more explicit and verifiable accessibility requirements. However, this progression was not uniform. The findings suggest that structured specification methods should be accompanied by differentiated pedagogical support to ensure that accessibility becomes a meaningful and sustained part of learners' design and development practices.

6 Limitations

Yin (2018) identified four tests - Construct, Internal and External Validity, and Reliability - that can be used to evaluate the quality of a case study. In our research, we conducted our study in a real-world setting, with participants from diverse backgrounds and experiences. To ensure accuracy, we collected data from multiple sources, including a questionnaire, group activity, and observation, and used both qualitative and quantitative techniques. As an exploratory study conducted without a control group, internal validity is limited. It is not possible to definitively attribute improvements in requirement specification to any single instructional component, such as the WCAG lecture, as other factors such as prior industry experience or group dynamics may have influenced participant performance. The study was also constrained by its context: it was conducted in a single undergraduate course at one institution, involving participants in the middle stage of their academic training. While the instructional design and evaluation criteria were documented in detail to enhance reliability, variations in participant engagement also impacted outcomes. Some groups demonstrated limited participation or collaboration, which may have affected the quality of their deliverables independently of the teaching strategies applied. Despite these limitations, the study provides meaningful insights into how structured pedagogical interventions such as the use of BDD and WCAG can support the development of accessibility-aware software engineers. Future research could benefit from longitudinal approaches, the inclusion of control groups, and the integration of peer feedback or frame strategies to better support participants who struggle with abstract or unfamiliar concepts like accessibility.

7 Final Considerations and Future Work

This study presented two exploratory interventions designed to improve how accessibility is specified during software development. The first intervention assessed undergraduate students' baseline knowledge and the main challenges they face when addressing accessibility in practice. The second intervention introduced a structured method that combined Personas, User Stories, BDD scenarios, and WCAG guidelines to support the articulation of accessibility-related requirements.

Our findings suggest the presence of a gap between the perceived importance of accessibility and participants' ability to apply it effectively. Initially, most participants relied on intuition and prior experiences rather than formal standards. However, after guided instructional activities, they were generally able to produce more precise, WCAG-aligned, and testable requirements. The use of Personas and BDD scenarios appeared to help foster empathy and structure, while WCAG helped ground their specifications in recognized accessibility criteria. These results indicate that the integration of accessibility into software engineering education through practical, scaffolded activities may be a promising direction. They also suggest that structured methods could help bridge the gap between awareness and implementation.

As future work, we plan to expand the evaluation of the method with practitioners in real-world environments. We also anticipate refining the method by incorporating feedback from this study and developing supporting materials to better facilitate its integration into agile workflows.

Authors' Contribution

RV and SM contributed to the conception and validation of this work. RV, NG, and SM contributed to writing (review and editing) and supervision. All the authors performed the experiments, with RV and NG serving as the main contributor and writer of this manuscript. All authors read and approved the final manuscript.

Competing Interests

The authors declare that they have no competing interests.

Availability of Materials

All the instructional materials and questionnaires used in this study are available at `https://doi.org/10.6084/m9.figshare.28684661.v1`.

Acknowledgements

We thank all participants who contributed to our study. Sabrina Marczak thanks CNPq (313181/2021-7), Renata Vinadé thanks CAPES (88887.908352/2023-00) and Natalya Goelzer thanks Dell Brazil using incentives of the Brazilian Informatics Law (Law no. 8.2.48, year 1991) for their financial grants.

References

Abascal, J., Barbosa, S. D., Nicolle, C., and Zaphiris, P. (2016). Rethinking universal accessibility: A broader approach considering the digital gap. *Universal Access in the Information Society*, 15(2):179–182.

Acosta-Vargas, P., Luján-Mora, S., and Salvador-Ullauri, L. (2017). Web accessibility polices of higher education institutions. In *Proc. of Int'l. Conf. on IT Based Higher Educaction and Training*, pages 1–7, Ohrid, MK. IEEE.

Akoumianakis, D. (2009). Managing universal accessibility requirements in software□intensive projects. *Software Process: Improvement and Practice*, 14(1):3–29.

Alexander, I. F. and Maiden, N. (2004). *Scenarios, Stories, Use Cases: Through the Systems Development Life-Cycle*. Wiley Publishing, Hoboken, USA, 1st edition.

Alshayban, A., Ahmed, I., and Malek, S. (2020). Accessibility Issues in Android Apps: State of Affairs, Sentiments, and Ways Forward. In *Proc. of Int'l. Conf. on SE*, pages 1323–1334, Seoul, KR. ACM.

Bi, T., Xia, X., Lo, D., Grundy, J., Zimmermann, T., and Ford, D. (2022). Accessibility in Software Practice: A Practitioner's Perspective. *ACM Transactions on Software EngineeringMeth.*, 31(4):26.

Cakir, A. E. (2009). Accessibility in IT. In Schlick, C. M., editor, *Industrial Engineeringand Ergonomics*, chapter 35, pages 469–480. Springer, Berlin, DE.

Case, B. J. (2008). Universal design. https://images.pearsonassessments.com/imag es-/tmrs/tmrs_rg/UniversalDesign.pdf.

Chen, J., Chen, C., Xing, Z., Xu, X., Zhu, L., Li, G., and Wang, J. (2020). Unblind your apps: Predicting natural-language labels for mobile gui components by deep learning. In *Proc. of Int'l. Conf. on SE*, pages 322–334, Seoul, KR. ACM.

Cohn, M. (2004). *User Stories Applied: For Agile Software Development*. Addison-Wesley Longman Publishing Co., Inc., Redwood City, USA, 1st edition.

Darvishy, A. (2017). E-accessibility supports researchers with disabilities. In *Proc. of Int'l. Conf. on Info. and Communication Technology and Accessibility*, pages 1–2, Muscat, OM. IEEE.

de Castro Pinto, F. A., Brandão, A. A. F., and Siqueira, F. L. (2022). Design thinking and non-functional req. elicitation: A survey. In *WER 2022*.

de Oliveira, R. F., da Mota Moura, A. M., and Leite, J. C. S. P. (2018). Reengineering for Accessibility: A Strategy Based on Software Awareness. In *Proc. Brazilian Symp. on Soft. Quality*, page 180–189, Curitiba, Brazil. Association for Computing Machinery.

Domah, D. and Mitropoulos, F. J. (2015). The nerv methodology: A lightweight process for addressing non-functional requirements in agile software development. In *SoutheastCon 2015*, pages 1–7.

El-Glaly, Y. N. (2020). Teaching Accessibility to Software EngineeringStudents. In *Proc. of ACM Technical Symp. on Computer Science Edu.*, pages 121–127, Portland, USA. ACM.

Falessi, D., Juristo, N., Wohlin, C., Turhan, B., Münch, J., Jedlitschka, A., and Oivo, M. (2018). Empirical software engineering experts on the use of students and professionals in experiments. *Empirical Software Engineering*, 23(1):452–489.

Gartner, M. (2012). *ATDD by Example: A Practical Guide to Acceptance Test-Driven Development*. Addison-Wesley Professional, Boston, USA, 1st edition.

Glinz, M. (2007). On non-functional requirements. In *15th IEEE International Requirements Engineering Conference (RE 2007)*, pages 21–26.

Goelzer, N. M. and Marczak, S. (2024). Promoting Quality in BDD Scenarios Using Checklist: An Investigation from the Perspective of Novice Professionals. In *Proc. Brazilian Symp. on Software Quality*, SBQS '24, page 341–350, New York, NY, USA. Association for Computing Machinery.

Hoffmann, A., Schulz, T., Hoffmann, H., Jandt, S., Roonagel, A., and Leimeister, J. M. (2012). Towards the use of software requirement patterns for legal req. In *Proc. Int'l Req. Engineering Efficiency Workshop*, Essen, DE. SSRN.

IBGE (2012). Características gerais da população, religião e pessoas com deficiência. `https://biblioteca.ibge.gov.br/visualizacao/periodicos/94/cd_2010_religiao_deficiencia.pdf`. Accessed: March 2025.

IBGE (2022). Pessoas com Deficiência e as Desigualdades Sociais no Brasil. `https://biblioteca.ibge.gov.br/visualizacao/livros/liv101964_informativo.pdf`. Accessed: March 2025.

Info. Society and Media (2005). An info. society open to all. `https://ec.europa.eu/Information_society/doc/factsheets/012\protect\discretionary{\char\hyphenchar\font}{}{}eaccessibility.pdf`. Accessed: March 2025.

ISO (2011). *ISO/IEC-25010 - Syst. and Software engineering – Syst. and Software Quality Req. and Eval. (SQuaRE) – Syst. and Software Quality Models*. ISO.

Kaner, C. (2003). The power of 'what if...' and nine ways to fuel your imagination. *Software Testing and Quality Engineering Magazine*, 5:5.

Kawas, S., Vonessen, L., and Ko, A. J. (2019). Teaching Accessibility: A Design Exploration of Faculty Professional Development at Scale. In *Proc. Technical Symp. on Computer Science Education*, page 983–989, Minneapolis, USA. Association for Computing Machinery.

Kitchenham, B. and Pfleeger, S. L. (2007). Personal Opinion Surveys. In Shull, F., Singer, J., and Sjøberg, D. I., editors, *Guide to Advanced Empirical Software Engineering*, chapter 3, pages 63–92. Springer London, London, UK.

Kiyavitskaya, N., Krausová, A., and Zannone, N. (2008). Why eliciting and managing legal req. is hard. In *Proc. of Int'l. Workshop on Req. Engineering and Law*, page 26–30, Barcelona, Spain. IEEE.

Kotonya, G. and Sommerville, I. (1998). *Requirements engineering: processes and techniques*. Wiley Publishing.

Lazar, J., Dudley-Sponaugle, A., and Greenidge, K.-D. (2004). Improving web accessibility: a study of webmaster perceptions. *J. of Computers in Human Behavior*, 20(2):269–288.

Lucassen, G., Dalpiaz, F., Van Der Werf, J., and Brinkkemper, S. (2015). Forging high-quality user stories: Towards a discipline for agile requirements. In *Proc. Intn'l Requirements Engineering Conference (RE)*, pages 126–135.

Matoussi, A. and Laleau, R. (2008). A survey of non-functional requirements in software development process. LACL.

Miranda, D. (2021). A web accessibility requirements framework for agile development. In *Intl' Requirements Engineering Conference (RE)*, pages 474–479, New York, USA. IEEE.

Miranda, D., Araújo, J., and Liebel, G. (2024). A conceptual model for web accessibility requirements in agile development. In *Proc. of the Workshop on Multidisciplinary, Open, and RElevant Requirements Engineering*, page 15–21, Lisbon, Portugal. ACM.

Mylopoulos, J., Chung, L., Nixon, B., et al. (1992). Representing and using nonfunctional requirements: A process-oriented approach. *IEEE Transactions on software engineering*, 18(6):483–497.

National Disability Authority (2020). What is Universal Design. `https://universaldesign.ie/what-is-universal-design/`. Accessed: March 2025.

Nogueira, L. and Gonçalves, R. (2021). Health Sector Web Accessibility. In *Proc. of Iberian Conf. on Info. Systems and Technologies*, pages 1–6, Chaves, PT. IEEE.

North, D. (2020). Introducing BDD. `http://dannorth.net/introducing-bdd/`. Accessed: March 2025.

Oliveira, G., Marczak, S., and Moralles, C. (2019). How to Evaluate BDD Scenarios' Quality? In *Proc. Simp. Brasileiro de Engenharia de Software*, page 481–490, New York, NY, USA. Association for Computing Machinery.

Oliveira, R., Silva, L., Leite, J. C. S. P., and Moreira, A. (2016). Eliciting accessibility requirements an approach based on the nfr framework. In *Proc. of the Symposium on Applied Computing*, page 1276–1281, New York, USA. ACM.

Paiva, D. M. B., Freire, A. P., and de Mattos Fortes, R. P. (2021). Accessibility and Software EngineeringProcesses: A Systematic Lit. Review. *J. of Systems and Software*, 171:110819.

Patel, R., Breton, P., Baker, C. M., El-Glaly, Y. N., and Shinohara, K. (2020). Why Soft. is Not Accessible: Technology Professionals' Perspectives and Challenges. In *Proc. of Conf. on Human Factors in Computer Systems*, page 1–9, Honolulu, USA. ACM.

Pinheiro, V. and Marques, A. B. (2021). Accessibility-oriented design with a focus on autism aspects: designing a mobile application for autistic children's daily routine. In *Proc. Brazilian Symp. on Software Quality*, São Luís, Brazil. ACM.

Putnam, C., Dahman, M., Rose, E., Cheng, J., and Bradford, G. (2015). Teaching accessibility, learning empathy. In *Proc. of Int'l. ACM Conf. on Computers & Accessibility*, pages 333–334, Lisbon, PT. ACM.

Richards, J. T., Montague, K., and Hanson, V. L. (2012). Web accessibility as a side effect. In *Proc. of Int'l. ACM Conf. on Computer and Accessibility*, page 79–86, Boulder, USA. ACM.

Santos, E. C. S., Beder, D. M., and Penteado, R. A. D. (2015). A study of test techniques for integration with domain driven design. *Proc. Intern'l Conf. on Information Technology - New Generations, Las Vegas, USA*, 12(0):373–378.

Schulz, T. and Fritsch, L. (2014). *Accessibility and Inclusion Req. for Future e-Identity Solutions*, volume 8547 of *Lec-*

ture Notes in Computer Science, page 316–323. Springer, Paris, France.

Shirogane, J. (2014). *Support Method to Elicit Accessibility Requirements*, volume 432 of *Communications in Computer and Information Science*, page 210–223. Springer, Berlin, GER.

Smart, J. F. (2014). *BDD in Action: Behavior-Driven Development for the Whole Software Lifecycle*. Manning Publications.

Ullah, S., Iqbal, M., and Khan, A. M. (2011). A survey on issues in non-functional requirements elicitation. In *International Conference on Computer Networks and Information Technology*, pages 333–340.

United Nations (2022). World Population Prospects 2022. `https://population.un.org/wpp/Graphs/Probabilistic/PopPerc/60plus/76`. Accessed: March 2025.

United Nations (2023). Convention On The Rights Of Persons With Disabilities (CRPD). https://social.desa.un.org/issues/disability/crpd/convention-on-the-rights-of-persons-with-disabilities-crpd. Accessed: March 2025.

Vendome, C., Solano, D., Liñán, S., and Linares-Vásquez, M. (2019). Can everyone use my app? an empirical study on accessibility in android apps. In *Proc. of Int'l. Conf. on Software Maintenance and Evolution*, pages 41–52, Cleveland, USA. IEEE.

Vinadé, R. and Marczak, S. (2024). Unveiling developer perspectives: A survey on accessibility practices and requirements in software development. In *WER 2024*, Buenos Ayres, Argentina.

W3C (2018). Web content accessibility guidelines. Accessed: March 2025.

W3C (2024). About W3C. https://www.w3.org/Consortium/. Accessed: March 2025.

W3C (2024). Web Accessibility Initiative (WAI). https://www.w3.org/WAI/standards-guidelines/. Accessed: March 2025.

WHO (2024). Disability and Health. https://www.who.int/news-room/fact-sheets/detail/disability-and-health. Accessed: March 2025.

Yin, R. K. (2018). *Case study research and applications: design and methods*. SAGE, Los Angeles, USA, sixth edition edition.

Yusop, N. S. M., Grundy, J., and Vasa, R. (2016). Reporting usability defects: Do reporters report what software developers need? In *Proc. of Int'l. Conf. on Eval. and Assessment in SE*, page 1–9, Limerick, IE. ACM.