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Inclusive Digital Gaming Platform

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Abstract

The lack of accessibility in digital gaming platforms remains a significant barrier to equitable user participation. To address this issue, this article presents an inclusive solution developed as a multimedia project designed to promote access to digital games for any user through the ipcb.games platform. The platform offers features that enhance accessibility, including voice-based authentication, voice-assisted registration, facial recognition, visual and auditory feedback, and a simplified interface. It also enables users to submit their own games for subsequent approval and integration. The development process followed a multimedia project methodology, structured into phases of analysis, planning, design, production, testing, and validation. The proposal was informed by a systematic review of scientific literature on digital inclusion and accessibility, complemented by a comparative analysis of existing platforms. During usability testing, the platform was evaluated by approximately 50 teachers from different educational levels, who provided highly positive feedback. Future work includes implementing voice-controlled gameplay, enabling keyboard-based navigation, re-implementing a functional eye-tracking system, and creating pedagogical groups, further strengthening the platform's role in educational contexts.

Keywords: digital gaming platform; gamification; digital accessibility; voice commands; facial recognition

1. Introduction

The increasing digitalisation of society has brought about new opportunities for education, entertainment, and social inclusion, making technology an indispensable part of everyday life [1]. Digital games, which were once merely a form of leisure, now play a central role in multiple domains, demonstrating their potential to promote more accessible and inclusive learning experiences [2]. Prior work [3] highlights that developing digital games tailored to each learner's needs can help overcome barriers in education and cognitive development [4]. However, many digital platforms still pose barriers for users with disabilities or accessibility needs, particularly during initial interaction stages such as registration and login, which are critical to system acceptance and use [5]. In this context, inclusion and accessibility are essential pillars for developing fair and equitable digital solutions. It is therefore crucial that digital solutions incorporate accessible interfaces, alternative navigation methods, and personalisation options from the design stage to address diverse user needs. The creation of more inclusive digital environments should not be regarded merely as a technical choice, but as an ethical commitment to equity [6].

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This need motivated the development of the ipcb.games project aimed at creating an inclusive digital gaming platform accessible to all users, regardless of their limitations. The project employed a multimedia project methodology, structured into five phases: analysis and planning, design, production, testing, and maintenance [7]. The process began with the analysis and planning phase, which included a systematic literature review guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology [8] to identify best practices in digital accessibility and inclusion. The review revealed that, despite advances in some platforms, most still present obstacles at initial contact points, such as account creation, reinforcing the need for more user-centred solutions designed in accordance with universal accessibility principles [9]. A key highlight was the development of accessible registration and login mechanisms that meet diverse user needs, including traditional login, voice-based authentication, and facial recognition [10]. These options provide users with autonomy and flexibility, contributing to a more inclusive experience that aligns with established best practices.

The project combines theoretical analysis, as informed by a literature review, with the practical development of the platform, thereby enabling the proposed research questions to be addressed.

While the platform description is an important part of this work, the manuscript also makes an academic contribution by demonstrating how inclusive authentication mechanisms can be operationalised and empirically validated within a real-world digital gaming platform, thereby addressing gaps identified in prior accessibility research.

This article is structured as follows: Section 2 presents the research method, which is supported by a systematic review methodology, including the research questions, inclusion criteria, search strategies, results, data extraction and analysis, and discussion. Section 3 describes the platform development, including the multimedia project methodology, which is divided into the following phases: analysis and planning, design, production, testing and validation, and distribution and maintenance. Finally, Section 4 presents the conclusions and suggestions for future work.

2. Systematic Review of Literature

A detailed analysis of scientific studies on the development and impact of inclusive gaming platforms was conducted to gather as much relevant information as possible. The review followed the PRISMA [8], covering the following elements:

A. Research questions.
B. Inclusion criteria.
C. Search strategy.
D. Results.
E. Data extraction and analysis.
F. Discussion.

To guide the research, questions were defined that focused on the development of inclusive digital games and on existing platforms for game integration. These questions aimed to identify challenges, best practices, and features that could be implemented and improved on the platform under development. The formulated questions were as follows:

Research Question 1: How does the integration of accessible authentication mechanisms (voice and facial recognition) influence usability and inclusion in digital platforms?

Research Question 2: How do inclusive educational technologies help make learning more useful and accessible?

Research Question 3: How do serious games promote inclusion and participation among diverse audiences?

The inclusion criteria specify the characteristics the analysed articles must possess to be deemed suitable for review. All articles that did not meet these criteria were excluded from further analysis. For this study, the following inclusion criteria were established:

Criterion 1: Studies published between 2021 and 2025.

Criterion 2: Studies written in English.

Criterion 3: Studies with full text availability.

Criterion 4: Studies addressing digital accessibility, inclusive design, or the development of educational technologies, digital platforms, or serious games aimed at inclusion.

Criterion 5: Studies presenting discussions, proposals, or practical evidence related to usability, interaction, or the integration of accessible features in learning, entertainment, or digital rehabilitation contexts.

Criterion 6: The final selection was restricted to peer-reviewed journal articles, excluding conference proceedings, workshop papers, and other publication types.

The initial search was conducted across several academic databases, including ACM Digital Library and IEEE Xplore. The search terms used were: ((“game development” OR “digital games”) AND (“platforms” OR “features”)) OR ((“educational technology” AND “accessibility”) OR “serious games”). The search was carried out between November and December 2024. A total of 568 studies were initially identified, comprising 219 from IEEE Xplore and 349 from the ACM Digital Library, as illustrated in Figure 1. During the screening phase, 219 studies were excluded: 7 for duplication and 212 for not being journal articles, as only peer-reviewed journal papers were considered eligible at this stage. The remaining 349 studies were screened based on their titles and abstracts. During this phase, 314 articles were excluded for the following reasons: being outside the study’s thematic scope, addressing non-relevant application contexts, targeting populations not compatible with the research objectives, presenting a misaligned technological focus, or corresponding to ineligible study types. The remaining 35 studies advanced to the eligibility phase and were analysed in full. At this stage, 29 articles were excluded due to the absence of empirical evaluation or user validation, a primary focus not aligned with the research objectives, the use of technologies or approaches different from those analysed in this study, or unclear or insufficiently reported results. Consequently, 6 studies met all the established inclusion criteria and were selected through the systematic database search. In addition to the systematic database search, three additional studies were identified through external citation searching. These studies were included based on their direct relevance to the research objectives and their frequent citation in the selected literature. Although these studies fall outside the predefined inclusion criteria, they were retained for their seminal relevance and direct contribution to addressing the defined research questions. As a result, 9 studies were included in the final review (Figure 1).

After analysing the selected articles, Table 1 was created to summarise the extracted data, specifically the study title, year of publication, thematic domain, and target audience, enabling a more precise comparison of the scope and focus of the selected studies.

The authors of [11] analysed the use of voice recognition as an authentication method, highlighting privacy issues and usability challenges associated with this approach. The article discusses how dictating passwords may expose users to security risks and proposes solutions to reduce vulnerability, such as indirect voice authentication. The results indicate that although voice authentication has the potential to enhance accessibility for users with motor impairments, improvements are needed to increase reliability and reduce eavesdropping risks. The study concludes that the technology must be carefully adapted to strike a balance between accessibility and security.

Study [12] examined the accessibility and usability of a learning platform designed for students who are blind and deaf. The research involved three distinct groups (blind, deaf,

and deaf–blind), who tested a prototype with content adapted to different user needs. The findings indicated a generally positive attitude, though differences in perceived ease of use were observed across groups. The authors concluded that both accessibility and usability are fundamental for the development of inclusive educational platforms.

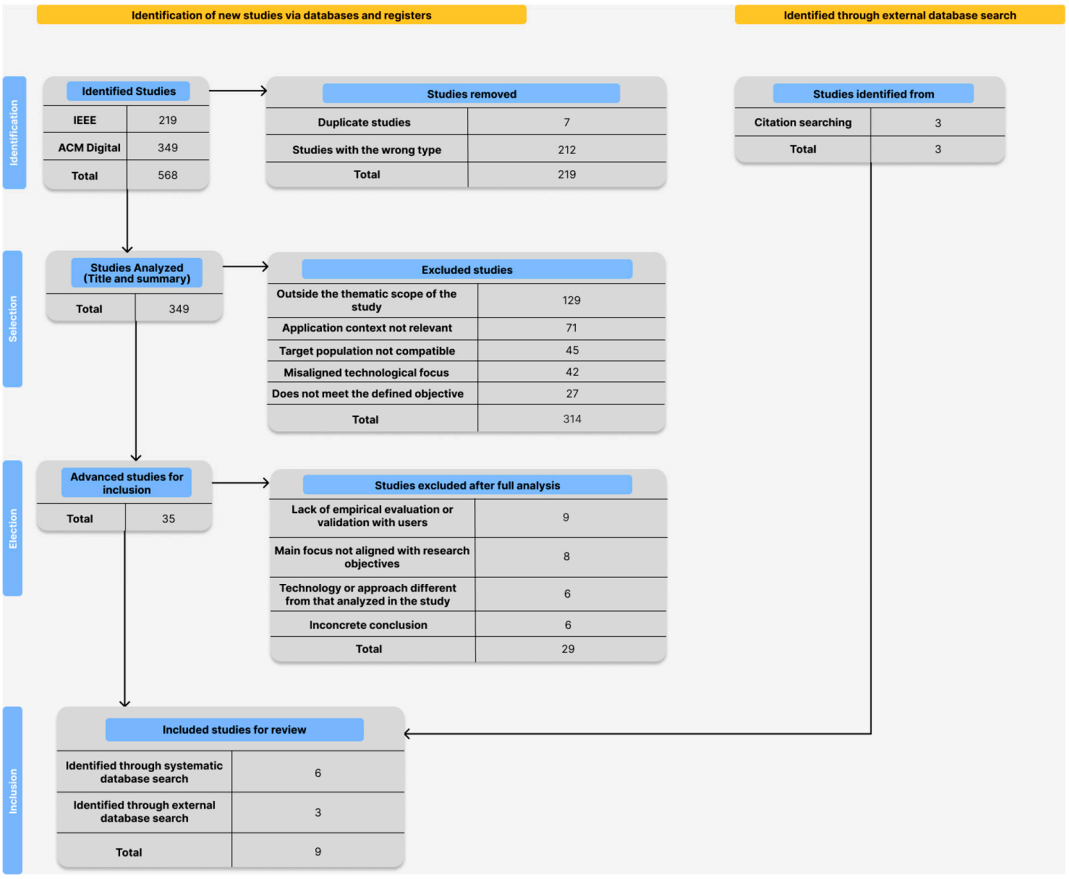

Figure 1. Flowchart of the research phases.

Table 1. Scientific studies analysed.

Study	Year of Publication	Thematic Domain	Target Audience
Don't listen! I am dictating my password! [11]	2009	Voice recognition/Authentication	People with motor disabilities (users of speech-based technologies)
Improving Accessibility in Online Education: Comparative Analysis of Attitudes of Blind and Deaf Students Toward an Adapted Learning Platform [12]	2021	Inclusive learning platforms	Blind and deaf students
Robot Delivered Cognitive Simulation Games for Older Adults [13]	2021	Cognitive Simulation games and ageing	Older adults
E-Learning Ecosystems for People with Autism Spectrum Disorder: A Systematic Review [14]	2023	E-Learning/Inclusive Education	People with autism
A Systematic Literature Review of Game-Based Assessment Studies: Trends and Challenges [15]	2023	Game-Based Assessment/Serious Games	Students and professionals

Table 1. *Cont.*

Study	Year of Publication	Thematic Domain	Target Audience
A Law of Diminishing Returns: Quantifying Online Accessibility for Engineering Students with Disabilities in the Wake of the COVID-19 Pandemic [16]	2024	Educational Technology/Online Learning Accessibility	Students with disabilities
Developing a Digital Game to Enhance Social Cognition Skills in Adolescents with ASD in a Multidisciplinary Context [17]	2024	Serious games/Game-Based Learning	Adolescents with Autism
Inclusive by design: Developing Barrier-Free Authentication for Blind and Low Vision Users through the ALIAS Project [18]	2025	Accessible authentication	Blind and low-vision users
Accessible authentication methods for persons with diverse cognitive abilities [19]	2025	Accessible authentication	People with diverse cognitive abilities

The study [13] explored how older adults perceived the usability and benefits of cognitive stimulation games delivered through a robot. The findings indicate that participants anticipated gains in memory, concentration, logical reasoning, and reaction time, while also recognising that the games could help them monitor their cognitive abilities. Despite these advantages, challenges were reported, including mismatches in language and imagery, occasional technical issues with interactive blocks, and difficulties arising from age-related visual limitations. Overall, the authors concluded that robot-mediated cognitive games represent a valuable and acceptable resource for this population, provided they are adapted to users' preferences, abilities, and cultural context.

The study [14] presents a systematic review of e-learning ecosystems for people with Autism Spectrum Disorder (ASD), analysing technologies such as virtual reality, mobile applications, robots and serious games within an ecological perspective that includes both technological components (platforms, software, infrastructure) and human actors (parents, teachers, therapists, psychologists and instructional designers). The review shows that most proposals focus on social and communication skills and that serious games and other interactive tools have notable potential to support engagement and skill development. However, it also highlights recurrent limitations, such as small and heterogeneous samples, short intervention durations, limited generalisability, and a lack of design guidelines and adaptive models tailored to different ASD profiles. The authors argue that future e-learning ecosystems for ASD should be designed as adaptive, multi-stakeholder environments, where technologies are aligned with pedagogical and therapeutic goals and quantitative evaluation methods are strengthened, which is particularly relevant for understanding how inclusive educational technologies can make learning more valuable and accessible in authentic contexts.

The authors of the study [15] conducted a systematic literature review of 65 empirical game-based assessment studies, analysing how digital games are used to assess learners' knowledge, competencies, and skills across different educational and professional contexts. The review shows that game-based assessment is primarily applied in K–16 education and focuses on evaluating cognitive and soft skills, such as problem-solving, communication, and collaboration. The findings highlight that game-based assessment benefits from the engaging and motivating nature of games, enabling the collection of rich interaction data,

personalised feedback, and adaptive assessment processes. The authors conclude that game-based assessment holds strong potential to enhance assessment practices by providing more dynamic, context-aware, and engaging evaluation environments. However, challenges remain regarding scalability, data analysis methods, and validation.

The study [16] examined accessibility barriers for engineering students with disabilities in online learning using a Universal Design for Learning (UDL) framework. The research identified three major accessibility dimensions: representation, action and expression, and engagement. Key findings revealed that accessibility factors significantly predicted students' perceived value of learning, with barriers including a lack of multiple ways to demonstrate comprehension, insufficient feedback, and limited instructional technologies. The authors conclude that implementing UDL principles in online educational technologies can help mitigate accessibility barriers and increase both usefulness and accessibility for students with disabilities.

Study [17] describes the interdisciplinary development of TEACOG, a serious game designed to train social-cognition skills in adolescents with Autism Spectrum Disorder (ASD) through interactive, scenario-based decision-making in everyday social contexts, such as restaurants, parties, online interactions, classrooms, and shopping situations. The development followed an iterative process that included requirements analysis, interface design with expert input, implementation in Unity with local data storage, and preliminary validation by usability experts and an autism specialist. The resulting prototype integrates features such as progress-tracking for therapists, guidance menus with social communication tips, and feedback after each decision. Expert assessment indicated that the game is promising and appropriate as a complementary therapeutic and educational tool. However, improvements are still required, including clearer tutorials, enhanced visualisation of results, and more flexible scenarios. The authors emphasise the need for extensive evaluation of interventions for adolescents with ASD to assess usability, playability, and long-term effectiveness, and illustrate how serious games based on interactive social scenarios may support social skills training in educational and therapeutic contexts.

Study [18] presents the ALIAS project, which aims to develop accessible authentication systems for Blind and Low-Vision (BLV) users to address critical gaps in digital accessibility and cybersecurity. Adopting a user-centred design approach grounded in cognitive ergonomics, the project follows a three-stage iterative methodology that includes needs assessment, prototype evaluation, and validation in real-world contexts. The findings highlight that traditional authentication methods, such as CAPTCHA and password-based mechanisms, pose significant barriers, while biometric approaches require careful, inclusive design to be accessible to BLV users. The authors conclude that authentication systems must balance accessibility and security, actively involving BLV users in the design process to ensure inclusive and usable solutions.

The authors of the study [19] analysed the accessibility of different authentication methods for users with diverse cognitive abilities, combining a systematic literature review with an empirical user study. The research involved an online questionnaire administered to 34 adult participants with cognitive impairments to identify usability challenges associated with traditional authentication mechanisms such as passwords, PINs, one-time passwords and CAPTCHA. The findings demonstrate that conventional authentication methods often constitute significant accessibility barriers, leading users to adopt insecure behaviours such as password reuse and the use of simplified credentials. In contrast, biometric authentication methods, particularly voice and facial recognition, were perceived as the most accessible and most straightforward to use, as they reduce memory load and interaction complexity. The study concludes that biometric approaches represent a promising solution for balancing accessibility and security and proposes a validated set of design guidelines

to support the development of inclusive authentication systems for users with diverse cognitive abilities.

Based on the studies analysed, it is possible to answer the research questions presented above:

Research Question 1: How does the integration of accessible authentication mechanisms (voice and facial recognition) influence usability and inclusion in digital platforms?

The analysis of the selected studies indicates that accessible authentication mechanisms play a crucial role in enhancing usability and promoting inclusion in digital platforms, particularly for users with disabilities who face barriers when interacting with traditional security systems.

Study [11] examined the use of voice recognition as an alternative authentication method, focusing on users with upper-body motor impairments who experience difficulties using conventional input devices such as keyboards and mice. The findings highlight that speech-based authentication can significantly improve accessibility and ease of interaction by enabling hands-free access. However, the study also identifies important usability, privacy, and security challenges, including speech recognition errors, a lack of feedback during password entry, and the risk of eavesdropping when passwords are dictated aloud. These results indicate that, while voice-based authentication has strong potential to enhance inclusion, its effectiveness depends on careful design choices that address reliability, user confidence, and privacy protection.

Complementarily, the ALIAS project [18] emphasises that authentication mechanisms are frequently a significant accessibility barrier for blind and low-vision users, largely due to their reliance on visual elements, complex interaction steps, and high cognitive demands. The study highlights that accessible approaches, including biometric solutions such as facial recognition and voice-based interaction, can improve usability by reducing cognitive load, simplifying authentication workflows, and aligning system behaviour with users' mental models.

More recently, the study [19] provided empirical evidence that traditional authentication methods such as passwords, PINs, one-time passwords, and CAPTCHAs remain largely inaccessible to users with diverse cognitive abilities. Based on a literature review and a user study involving individuals with cognitive impairments, the authors demonstrate that these mechanisms often lead to frustration, insecure practices (e.g., password reuse), and reduced autonomy. In contrast, biometric authentication methods, particularly voice and facial recognition, were perceived as the most straightforward to use, as they minimise memory demands, reduce interaction complexity, and better accommodate users' cognitive characteristics. The study further reinforces the importance of user-centred and cognitively informed design, proposing validated guidelines to support the development of inclusive authentication systems.

Taken together, these studies demonstrate that integrating facial authentication with voice-based mechanisms can substantially enhance usability and promote greater inclusion on digital platforms. These findings suggest that accessible authentication mechanisms are most effective when combined with guided interaction, confirmation stages, and continuous multimodal feedback. When developed through user-centred and cognitively informed design approaches and supported by appropriate privacy and security safeguards, such mechanisms enable users to interact with digital environments in a more autonomous and usable manner, while carefully balancing accessibility and security requirements.

Research Question 2: How do inclusive educational technologies help make learning useful and accessible?

In the field of inclusive educational technologies, several studies have highlighted the importance of these tools in enhancing accessibility and the overall usefulness of learning experiences.

The study [16] examined accessibility barriers for engineering students with disabilities in online learning, using a Universal Design for Learning (UDL) framework. The research identified that inclusive educational technologies make learning useful and accessible through multiple means of representation, action and expression, and engagement. Findings revealed that accessibility factors significantly predicted students' perceived value of learning, demonstrating that accessibility barriers are significantly associated with lower perceived value of learning, and that UDL-aligned practices can help mitigate these barriers.

Complementarily, study [12] evaluated an adapted learning platform for blind and deaf students, providing empirical evidence that accessibility alone is insufficient without adequate usability. The results indicate that learning technologies become more useful and accessible when accessibility features are integrated with user-centred interaction design, ensuring that adapted content is not only available but also easy to navigate and understand across different user groups.

Additionally, the systematic review presented in study [14] analysed e-learning ecosystems for people with Autism Spectrum Disorder (ASD), highlighting the role of serious games and other interactive technologies in supporting engagement and skill development. The authors emphasised that adaptive, multi-stakeholder educational environments aligned with pedagogical and therapeutic goals are crucial for making learning more useful and accessible in real-world contexts.

Overall, these studies indicate that inclusive design, adaptability and personalisation in educational technologies contribute significantly to increased perceived usefulness and to more equitable access to learning opportunities.

Research Question 3: How do serious games promote inclusion and participation among different audiences?

Serious games have emerged as an effective strategy for promoting participation and engagement across diverse audiences by providing interactive, motivating, and context-aware learning experiences that can be tailored to specific user needs and characteristics.

These findings are consistent with research [13] showing that robot-delivered cognitive stimulation games can enhance usability, engagement, and acceptance among older adults. The study indicates that participants perceived benefits in memory, attention, and problem-solving, particularly when the game design accommodated age-related needs, including visual clarity, appropriate task difficulty, and culturally familiar content. These results highlight the importance of usability-oriented, user-adaptive design in fostering participation among specific population groups.

Additionally, study [15], a systematic literature review of 65 empirical game-based assessment studies, demonstrates that game-based approaches are widely applied across multiple contexts, particularly in K–16 education and in medical and professional settings. The review highlights that the engaging and motivating nature of games supports sustained participation and allows for the assessment of cognitive and soft skills, such as problem-solving, communication, and collaboration. Although the primary focus of these studies is assessment rather than inclusion, the findings suggest that game-based environments can promote active learner involvement and meaningful participation across different educational and professional contexts.

Furthermore, study [17] describes the interdisciplinary development of TEACOG, a serious game designed to train social-cognition skills in adolescents with Autism Spectrum Disorder (ASD) through interactive, scenario-based decision-making in everyday social

contexts. Expert-based evaluation indicated that the game is a promising complementary tool in educational and therapeutic settings, supporting engagement and practice of social skills. The study also emphasises the importance of user-centred design, interdisciplinary collaboration, and iterative development processes in promoting participation among specific target audiences, while acknowledging the need for further usability and effectiveness evaluations with adolescents with ASD.

In summary, the reviewed literature indicates that serious games promote participation across different audiences by combining engaging interaction, adaptive design, and context-specific content. Their contribution to inclusion is particularly evident when games are developed according to accessibility, usability, and user-centred design principles. Nevertheless, challenges remain in systematically integrating universal design approaches and in conducting comprehensive evaluations involving end users, especially those with disabilities.

3. Platform Development

The development of the ipcb.games platform followed the typical methodology of a multimedia project [20], providing a flexible, iterative, and user-centred approach. This methodology enabled the organisation of the work into well-defined stages, facilitating adaptation based on feedback and the needs identified throughout the process. The project was therefore structured into five phases: analysis and planning, design, production, testing and validation, and finally, distribution and maintenance. The analysis and planning phase was essential for grounding the project, beginning with a systematic literature review following the PRISMA protocol [8] that identified best practices in accessibility and inclusion on digital platforms. In the design phase, the defined requirements were translated into detailed functional and technical specifications, along with the development of the use-case diagram illustrated in Figure 2, which graphically depicts the interactions between different user types and the platform. At this stage, the platform was designed primarily for desktop environments, as WebGL-based games require browser and hardware capabilities that are not consistently supported on mobile devices. From the diagram, it can be observed that the visitor, representing any individual accessing the platform without authentication, can perform basic actions such as consulting publicly accessible pages, registering, logging in, and playing games. Once authenticated, the user gains access to additional features, such as uploading games and viewing personal statistics and information. The teacher, who inherits the capabilities of a regular user, can also access global statistics for all users. Finally, the administrator, with the highest level of permissions, is responsible for managing users and validating pending games, ensuring that only approved games are made available on the platform.

The production phase implemented the previously defined decisions, resulting in a fully functional platform. This phase involved developing both the front-end and the platform's management logic. Technologies such as PHP [21], MySQL [22], HTML [23], CSS [24], and JavaScript [25] were used for the core functionalities, along with face-api.js [26] for facial recognition and the SpeechRecognition [27] and SpeechSynthesis [28] APIs for voice-command support. One of the strengths of this phase was the implementation of alternative registration and login methods, traditional, voice-based, and facial recognition, designed to address different user limitations, thereby promoting autonomy and inclusion. Testing and validation were conducted iteratively across multiple devices and browsers, including bug identification and correction, usability improvements, and accessibility adjustments to ensure the platform met the defined requirements. This phase also helped identify technical limitations that need to be addressed in the future, such as integrating eye-tracking. Finally, a forward-looking development perspective was established, including

features that will enable teachers to create student groups with access to individual and global statistics and to collect quantitative metrics to guide future improvements. Although grounded in a specific platform, the presented solutions reflect design principles that can be transferred to other inclusive digital systems.

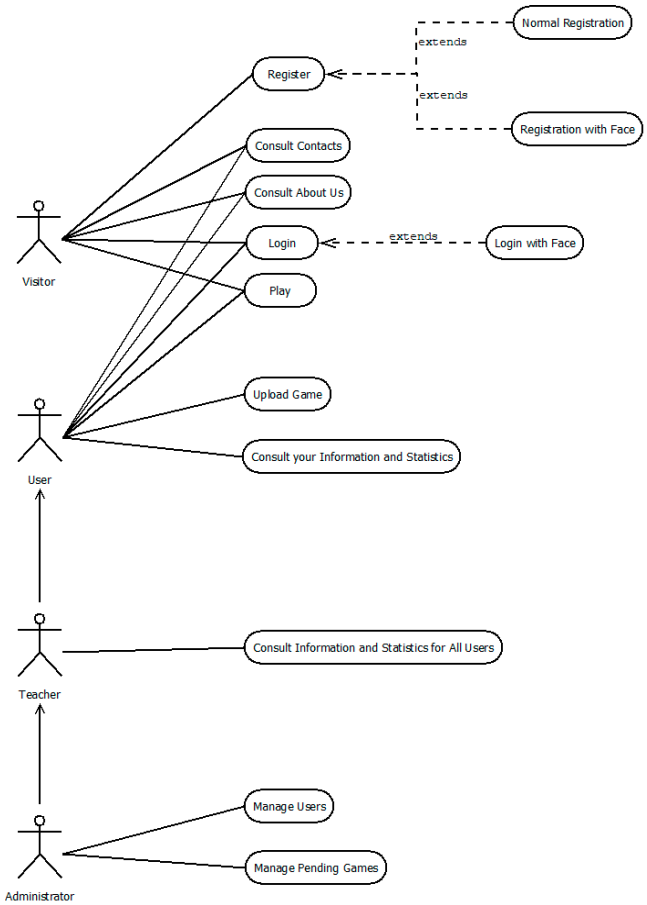

Figure 2. Use cases.

3.1. Production

The home page was designed to make the user experience intuitive, displaying the different games with their respective images, organised in rows and columns, as illustrated in Figure 3.

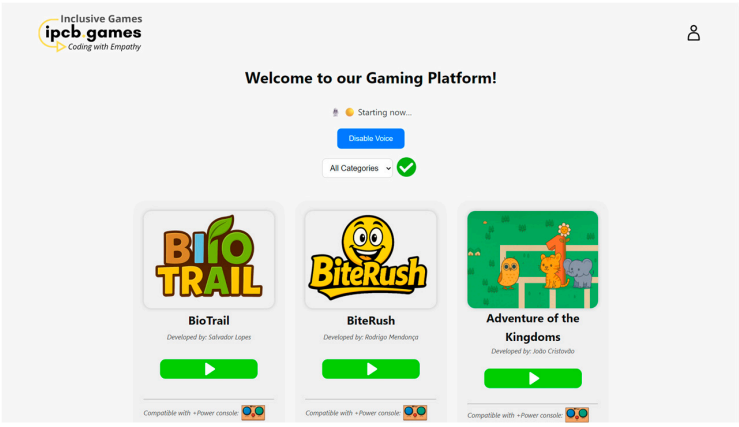

Figure 3. Platform Home Page.

At the top of the page, the logo is displayed, along with options to log in or register, as illustrated in Figure 4.

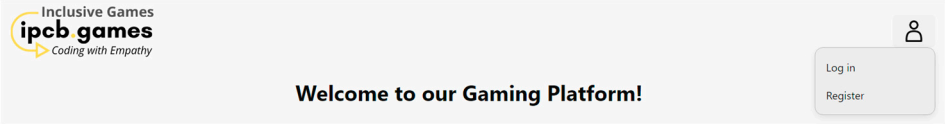

Figure 4. Top of the Home Page.

When the user logs in, their name is displayed to the left of the user button, which opens a new menu. In this menu, the user can access the page to upload a game they wish to integrate into the platform, a page with their personal information and statistics, and, finally, the option to log out, as shown in Figure 5.

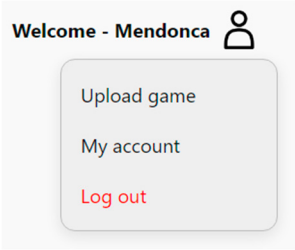

Figure 5. Logged-in User.

To promote the inclusion of people with motor difficulties or other limitations and to reach as many users as possible, a voice-command system was implemented. This system enables users to navigate the platform's various pages using their voice. The feature is activated after the first touch on the page because, for security reasons and due to restrictions imposed by some browsers (such as Google Chrome), voice functionality can only be enabled after the first manual interaction with the page, such as a click or screen tap. The first message always informs the user which page they are on (e.g., "You are on the login page", "You are on the registration page"). Then, the system informs the user that they may speak after hearing a sound cue: "When you hear this sound beep, you may speak." This sound was implemented to indicate when the user can start speaking clearly. For users who do not wish to use voice commands, it is possible to turn off this feature by clicking on "Disable Voice", as shown in Figure 6. From a research perspective, this implementation provides practical evidence that voice-based interaction can reduce entry barriers and improve perceived usability on inclusive platforms.

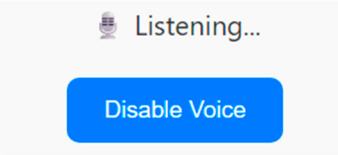

Figure 6. Button to Disable Voice.

To simplify game browsing, users can filter games by categories associated with each game. The available categories include: 2D, 3D, Arcade, Educational, Maze, Puzzle, and Board, as shown in Figure 7.

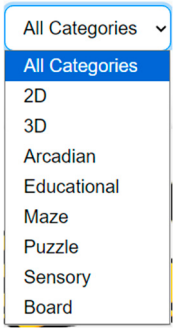

Figure 7. Category Types.

The games are displayed in a grid, where the user can view a thumbnail for each game, its title, author, and a button to start the game, as shown in Figure 8. All games were developed in Unity [29] and later exported to WebGL.

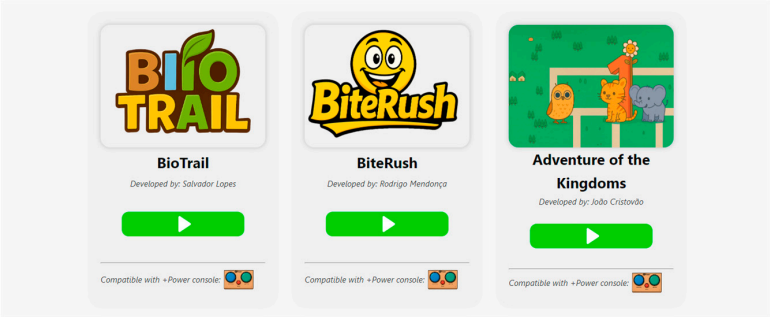

Figure 8. Representation of Games on the platform.

When a game is launched, the user is redirected to a new page where the game appears minimised. Before starting, confirm that the browser meets the gameplay requirements, including support for WebGL 2.0 and a 1080 p monitor or higher, as illustrated in Figure 9. These requirements are currently necessary because the games were developed for these specifications; otherwise, this warning may be removed in the future.

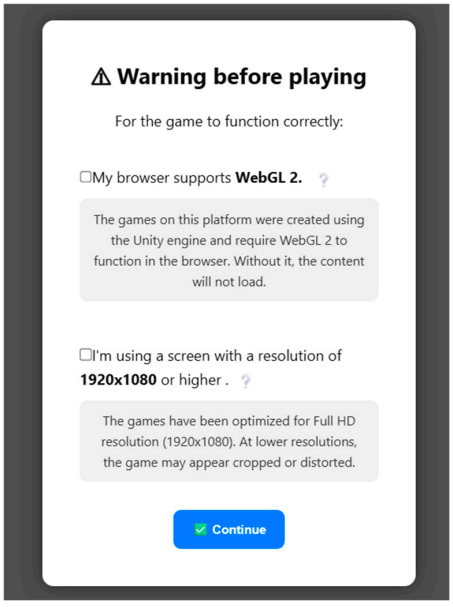

Figure 9. User Warning Before Playing.

After confirmation, the game opens in a minimised view and may appear misaligned depending on how it was developed. To correct this issue, the user must maximise the game window, as shown in Figure 10.

Figure 10. Game Start.

The game upload page enables any user with a Unity game configured for WebGL to submit it for inclusion on the platform. To submit a game, a form must be completed with the following information: name, author, image, game file, email, and a brief description. Only .png, .jpg, and .jpeg formats are accepted for the game image, and only .zip files are permitted for the game build.

To guide users correctly, a yellow warning-style button was created, along with detailed Unity export instructions to ensure platform compatibility. The user must follow the steps below to submit the game properly:

1. Open the menu File > Build Settings.
2. Select WebGL as the platform and click Player Settings.
3. In the Player tab, under Publishing Settings, set the Compression Format option to Disabled.

The "My Account" page adapts according to the type of user authenticated on the platform. For administrators, as illustrated in Figure 11, the page provides an overview and statistics of the platform's activity, facilitating management and analysis of usage. The page displays information such as the username and the user type. This layout is identical for both administrators and regular users. It also presents global platform statistics, including the total number of plays, the total number of registered users, the number of available games, the most common disability among users, the most representative age group, the top 5 most-played games, and the top 5 most active users. These insights are essential for future decision-making, such as identifying areas for improvement and understanding which types of games users engage with most.

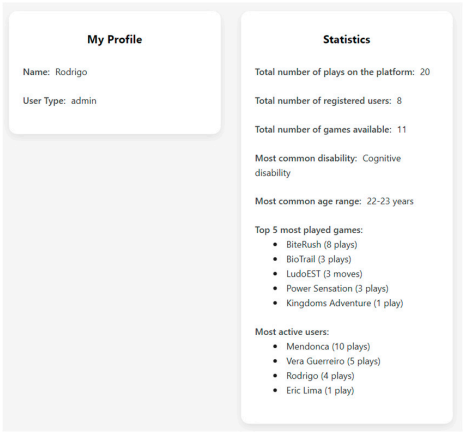

Figure 11. My Account Page—Admin View.

For a regular user, as illustrated in Figure 12, the page is simplified, focusing only on the user's activity and personal statistics. The information presented includes the most-played game on the platform, the total number of different games played, the total number of plays performed, the percentage of games played (relative to the total number of games available on the platform), and the top 3 most-played games.

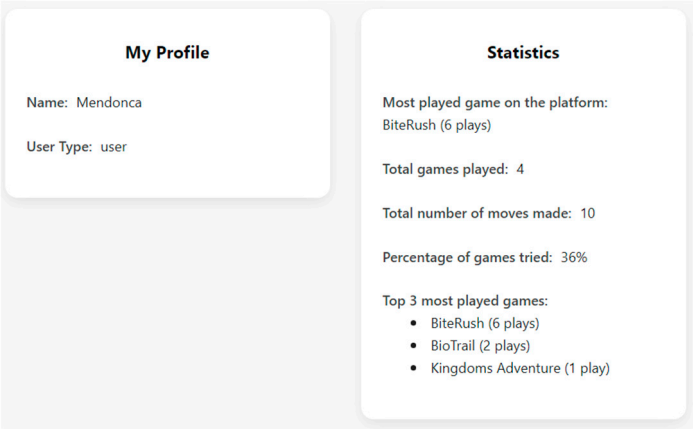

Figure 12. My Account Page—User View.

For administrators, a page called "User Management" is available, which allows viewing all user information, editing user roles, and removing registered users from the platform, as shown in Figure 13. There are two tables: one for users registered through the standard method (i.e., registrations completed via written or voice form), where administrators can view the ID, name, email, user type, date of birth, and any disabilities; and another for users registered via facial recognition (i.e., registrations completed using facial data), where the administrator can view the ID, name, facial ID, and user type of each user.

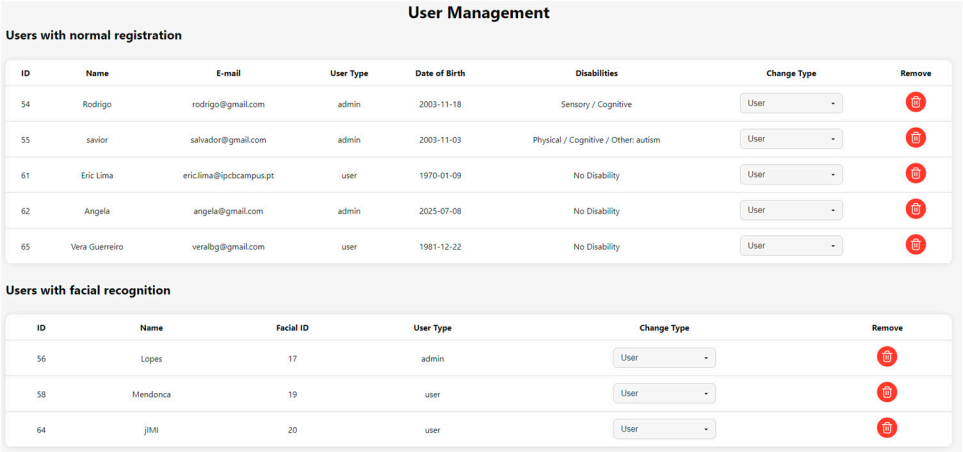

Figure 13. User Management Page—Admin View.

The administrator can also access the "Pending Game Management" page to view the games submitted by users that have not yet been validated, as illustrated in Figure 14. On the table displayed on the page, the administrator can see the game ID, the name provided by the user, the preview image, the author, the game creator's email (in case contact is required), a summary of the game, a button to test the game, a set of checkboxes to select the appropriate categories, a button to approve the game and make it publicly available to all users, and finally, a button to remove the pending game. To manage the game categories

available on the platform, a button links to a page where existing categories can be edited and new ones created.

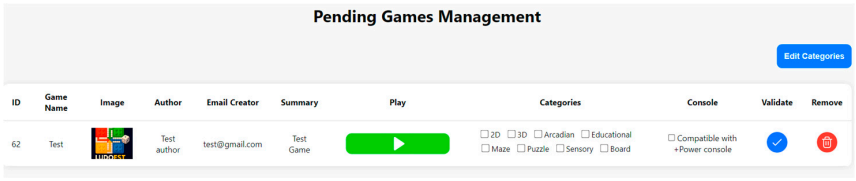

Figure 14. Pending Game Management Page—Admin View.

One of the main features of the ipcb. The game's platform features a voice-integration system implemented on both the login page (Figure 15) and the registration page (Figure 16). This feature allows any user, regardless of limitations, to log in or register without using a keyboard.

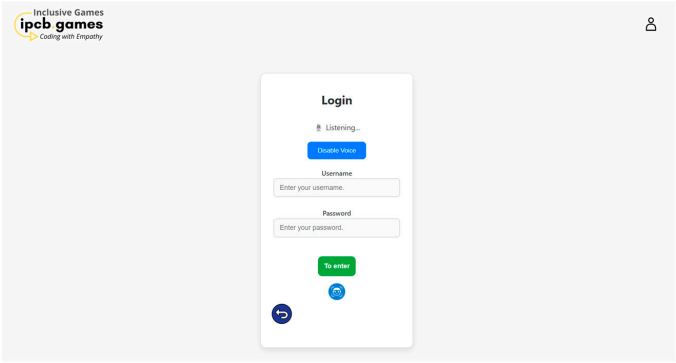

Figure 15. Login Page.

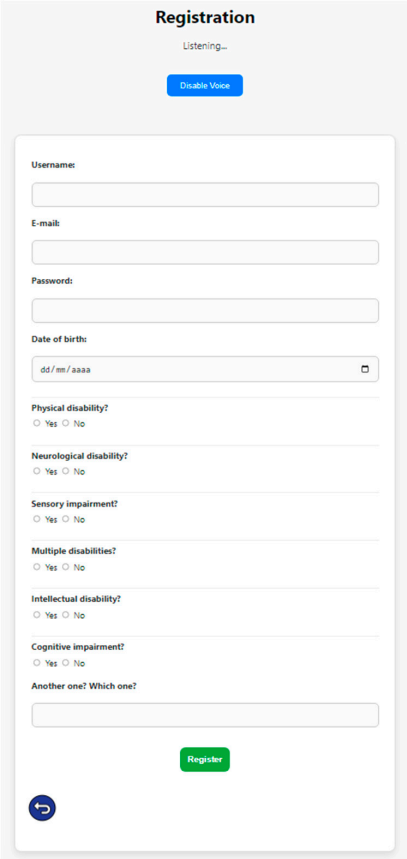

Figure 16. Registration Page.

On these pages, the user can choose to interact via keyboard or voice system. When accessing the page, the voice functionality is activated with a brief spoken instruction using the SpeechSynthesis API [28], which requests login or registration information. Then, an audio signal (beep) generated by the Web Audio API [30] is played to indicate when the user may speak. Data collection proceeds step by step through the SpeechRecognition API [27], which transcribes the user's speech. This work introduces a multimodal, accessible authentication model grounded in sequential confirmation, auditory feedback, and principles of reduced cognitive load. By combining voice-based interaction with confirmation loops, the model supports autonomous, error-tolerant authentication, addressing common accessibility barriers faced by users with motor and cognitive impairments.

All data are automatically inserted into the form fields using JavaScript [25], and once all fields are completed, the system submits the form without requiring manual clicking. At the end of the registration process, the system prompts for global confirmation via commands such as "register" or "cancel". Throughout the entire process, visual and auditory feedback is provided to the user, such as status messages like "🎤 Listening...", "🛑 Waiting for instructions...", "☑ Form completed!" or "☑ Login completed" as well as confirmation and error sounds. Additionally, on the login page, the system supports alternative commands, such as "login with face," which redirect the user to the facial recognition authentication page. This command ensures access to another page without manual clicks.

Finally, the user can turn off the voice system at any time, reverting to traditional keyboard-based input.

This functionality was developed using the following technologies:

- SpeechRecognition API [27]—to capture and interpret voice commands.
- SpeechSynthesis API [28]—to provide spoken instructions and confirmations.
- Web Audio API [30]—to generate readiness tones (beep).
- JavaScript [25]—to populate form fields and trigger automatic submission.
- PHP (fazLogin.php and fazRegisto.php) [21]—to process the data and return responses.
- FileZilla [31]—server provided by IPCB, used to establish FTP/SFTP connection, enabling file upload, updates, and organisation of project files.

Another key feature of the ipcb.games platform is the implementation of a facial recognition system, which is available on both the login and registration pages. This functionality further enhances the platform by providing an additional access alternative for users with disabilities or accessibility needs. When accessing these pages, the user is prompted to grant camera access, and a frame is displayed on the screen to help the user position themselves correctly. After detecting the face, the system utilises the face-api.js library [26], which contains pre-trained neural networks, to generate a facial descriptor represented as a vector containing the user's facial characteristics. This design choice aligns with and extends prior studies on accessible authentication by embedding biometric mechanisms within a broader, user-centred platform context.

In the case of login, as illustrated in Figure 17, the captured descriptor is sent to the server, where it is compared with the registered users' descriptors in the database. If a match is found, the user is automatically authenticated, receives a welcome message, and is redirected to the platform's home page. If the face is not recognised, the system provides visual and audio feedback, including error messages, and allows new attempts. In the case of registration, as shown in Figure 18, after detecting the face and verifying that it is not already registered, the system prompts the user to enter a username, which is then associated with the corresponding facial descriptor. The vector containing the user's facial features is sent to the database, allowing the face to be used for login. In the event of an error, an empty username, or a technical failure, visual feedback is displayed to indicate the

issue. If a person registering already has a face registered in the system, they are recognised and automatically redirected to the login page.

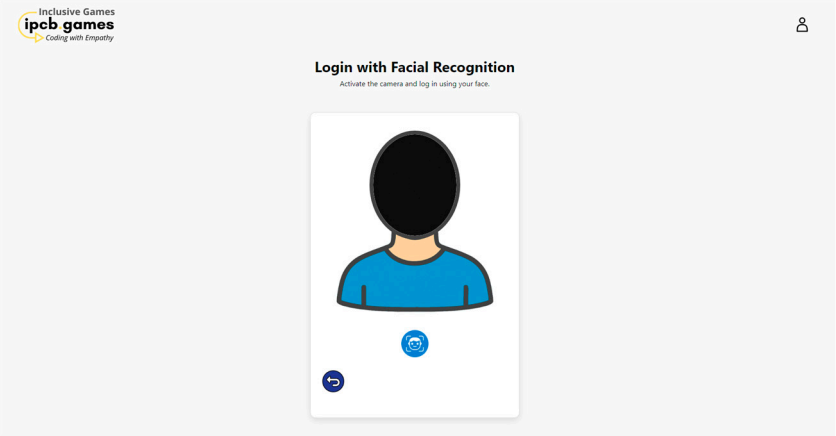

Figure 17. Login with Facial Recognition.

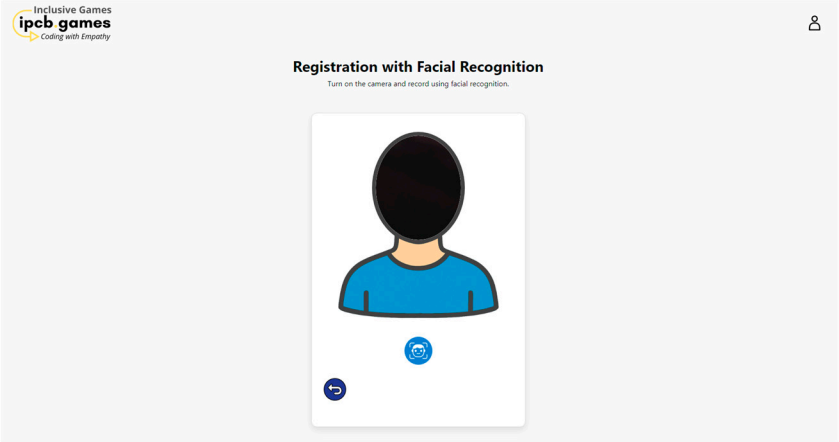

Figure 18. Registration with Facial Recognition.

Throughout the entire process, visual and auditory feedback is provided, with status messages such as "Loading facial model...", "Recognition successful", or "Face not identified", along with confirmation and error tones.

The facial recognition implementation is based on the following technologies:

- JavaScript [25]/HTML [23]—interface control, camera access, and user interaction.
- face-api.js [26] + TensorFlow.js [32]—face detection, landmark mapping, and recognition using neural networks.
- PHP (login_face.php, register_face.php, verifica_rosto.php) [21]—communication with the database, descriptor comparison, and secure storage.
- FileZilla [31]—server provided by IPCB (games.ipcb), enabling FTP/SFTP connection for file upload, updates, and organisation.
- Adminer [33]—storing users and their encoded facial data.

3.2. Testing and Validation

The testing and validation phase was essential to ensure that the platform operated correctly and met the defined requirements. Detailed, interactive tests were conducted across various environments, browsers, and devices. These tests enabled the identification of errors and limitations, the implementation of continuous improvements, and the adaptation of the platform to meet the real needs of users, including those with physical,

sensory, and cognitive disabilities. This process validated the proposed solutions against the initial research questions and demonstrated that integrating accessible authentication and interaction mechanisms effectively improves platform usability and inclusion.

One of the main focuses was validating the voice-command systems, especially on the registration and login pages, where the complexity of the data entered requires a high degree of recognition accuracy.

During testing, several issues were identified in the voice-command system, namely:

- Voice recognition interrupted: on multiple occasions, it was observed that voice recognition was abruptly interrupted whenever the speech synthesis system (speechSynthesis) spoke at the same time. This caused direct conflicts between speechSynthesis (which provides instructions to the user) and speechRecognition (which waits for the user's response), leading to microphone access interruptions or the loss of the spoken phrase. To address this issue, a forced delay was implemented after each spoken instruction, ensuring that speech output was completed before recognition began.
- Voice recognition failure: errors were detected in the recognition of voice commands in fields such as email and in the selection of disability checkboxes. In the case of email input, transcription errors frequently occurred with characters such as "@", "dot", and certain specific words. For the disability selection system, special handling was required, including semantic interpretation and visual interface updates.
- Voice-disable button: during testing, an intermittent malfunction was identified in the voice-disable button. Although the JavaScript code was identical across pages, the button did not always turn off voice recognition correctly.

During testing of the game-upload functionality, which allows users to add new games to the platform by uploading a .zip file, a critical issue was identified: the absence of a temporary folder on the server. The observed behaviour was that, after selecting the .zip file and submitting the form, PHP did not receive the file as expected. To diagnose the issue, phpinfo() was executed directly on the server, revealing that the upload_tmp_dir directive was set to no value, as shown in Figure 19. This meant PHP lacked a valid temporary directory to store uploaded files. As a result, .zip files were not even temporarily saved on the server, and the upload silently failed—that is, without displaying any visible error message, making the troubleshooting process more complex. Since the platform was hosted on an external server (without direct access to php.ini), it was not possible to manually define the upload_tmp_dir value. The issue was resolved by creating a temporary directory with appropriate write permissions. As direct access to php.ini was unavailable, the upload_tmp_dir parameter was dynamically defined in the PHP code to point to this directory. Additionally, it was necessary to ensure proper permissions on the server, which required automatically inserting the .htrw file into all relevant folders. This approach enabled .zip files to be correctly processed during upload, ensuring the feature functioned properly.

upload_max_filesize	128M	128M
upload_tmp_dir	*no value*	*no value*
user_dir	*no value*	*no value*

Figure 19. php.info.php with empty upload_tmp_dir.

The platform was tested on various browsers, and it was observed that not all were compatible with the voice-recognition API. One example was Firefox, which does not support it, making it impossible to use the voice-command system. At the beginning of the platform's development, the possibility of integrating an eye-tracking system was considered to enable users with motor limitations to interact solely with their eyes, as

illustrated in Figure 20. For this purpose, tests were conducted using libraries such as WebGazer.js, which use the computer's webcam to detect eye position and translate it into screen-navigation coordinates. However, despite the technology's potential, it quickly became clear that webcam-based eye tracking presented several limitations that hindered its practical implementation. The first issue was system accuracy. Even after the initial calibration, the cursor moved erratically and with a significant margin of error, particularly near the screen edges. This inaccuracy made selecting buttons or menus difficult, resulting in a frustrating user experience.

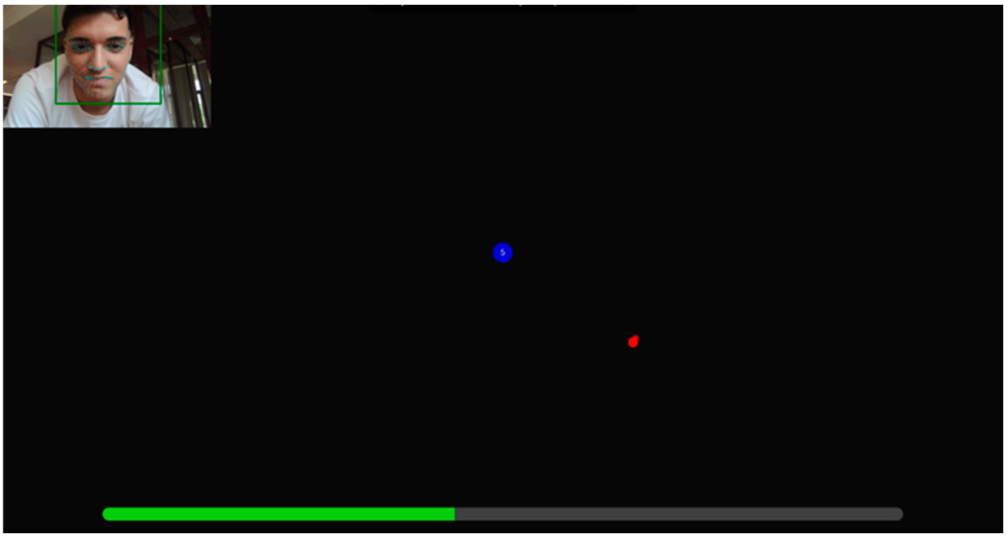

Figure 20. Eye-Tracking Calibration Page.

Additionally, the refresh rate of standard webcams, typically limited to 15 or 30 frames per second, was insufficient to capture eye movements smoothly and in real time. It was also observed that any slight change in the user's position required recalibration, which compromised continuous use of the system. Finally, it became evident that achieving acceptable performance would require specialised hardware (such as dedicated eye-tracking sensors), which was not feasible within the project's scope, given the goal of ensuring functionality with resources available to most users. Therefore, the decision was made not to include this feature in the final version of the platform.

The platform was evaluated by approximately 50 teachers from different educational levels, who provided highly positive feedback regarding usability, accessibility, and overall user experience. Participants were adults with teaching experience in educational contexts, recruited through institutional dissemination. Participation was voluntary and anonymous. To support this evaluation, a structured questionnaire was created with satisfaction questions rated on a scale from 1 (strongly disagree) to 5 (strongly agree). The responses enabled measurement of ease of use, confidence in the system, and perceived complexity. The graphics of Figures 21–30 were generated to display the average response for each question, as well as a separate graph presenting in Figure 31, the SUS (System Usability Scale) score, which provides a deeper assessment of usability.

The charts display each question at the top, numbered from 1 to 10, and each includes the average questionnaire responses, reflecting different dimensions of the user experience.

The results indicate that, overall, teachers considered the platform easy to use and reliable and felt comfortable using it without requiring excessive external assistance. The perceived complexity was low, and most participants reported a relatively quick learning process.

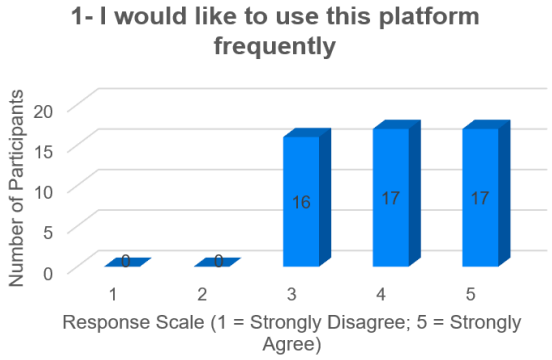

Figure 21. Distribution of responses regarding frequent use of the platform.

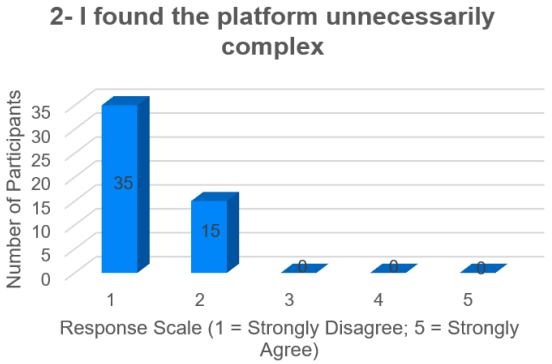

Figure 22. Distribution of responses regarding perceived platform complexity.

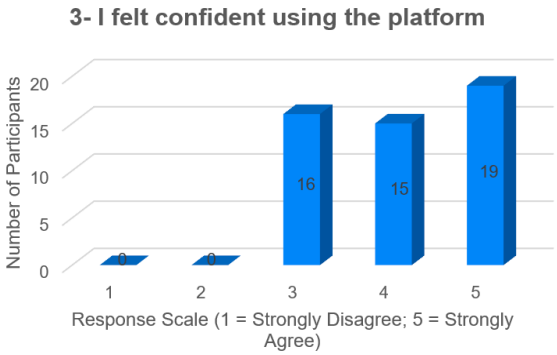

Figure 23. Distribution of responses regarding confidence when using the platform.

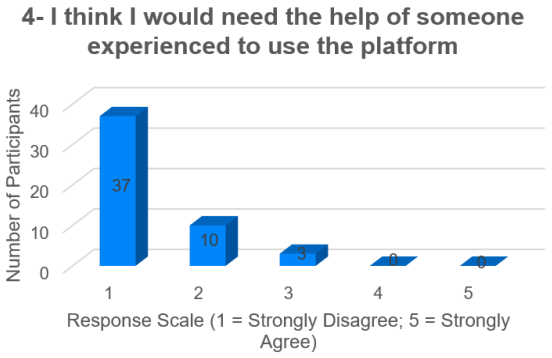

Figure 24. Distribution of responses regarding the need for assistance to use the platform.

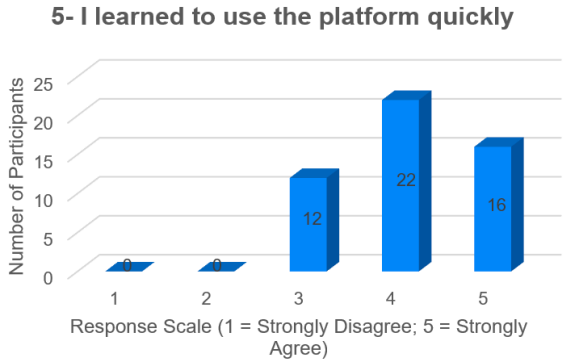

Figure 25. Distribution of responses regarding the speed of learning to use the platform.

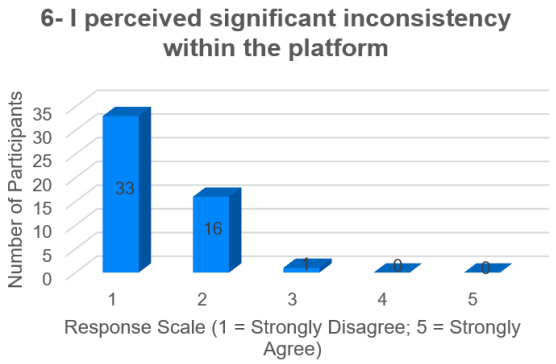

Figure 26. Distribution of responses regarding perceived inconsistency in the platform.

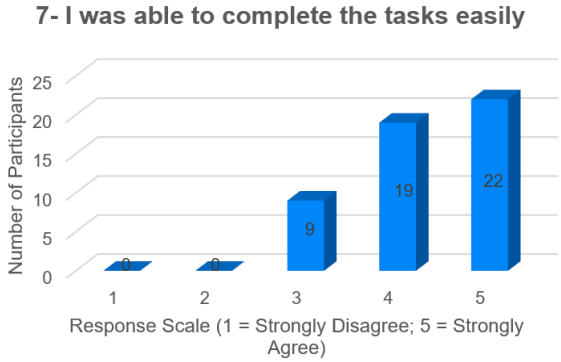

Figure 27. Distribution of responses regarding the ease of completing tasks on the platform.

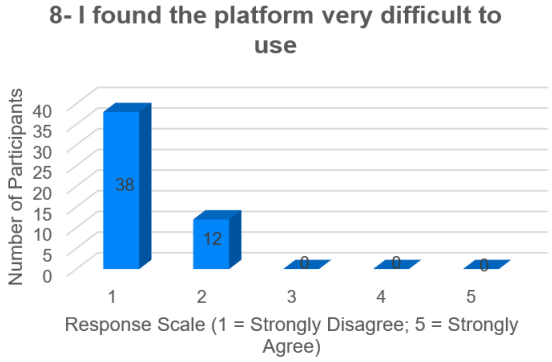

Figure 28. Distribution of responses regarding difficulty in using the platform.

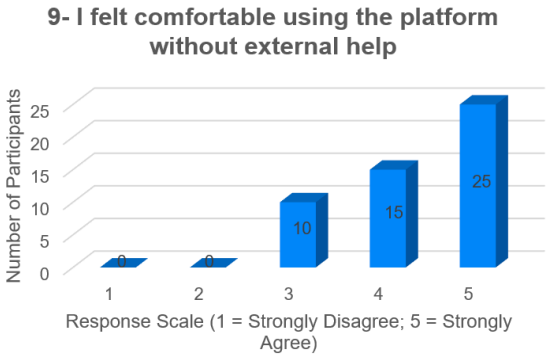

Figure 29. Distribution of responses regarding comfort in using the platform without external help.

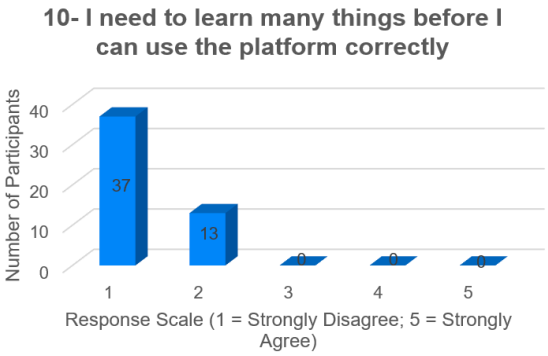

Figure 30. Distribution of responses regarding the need to learn things before correctly using the platform.

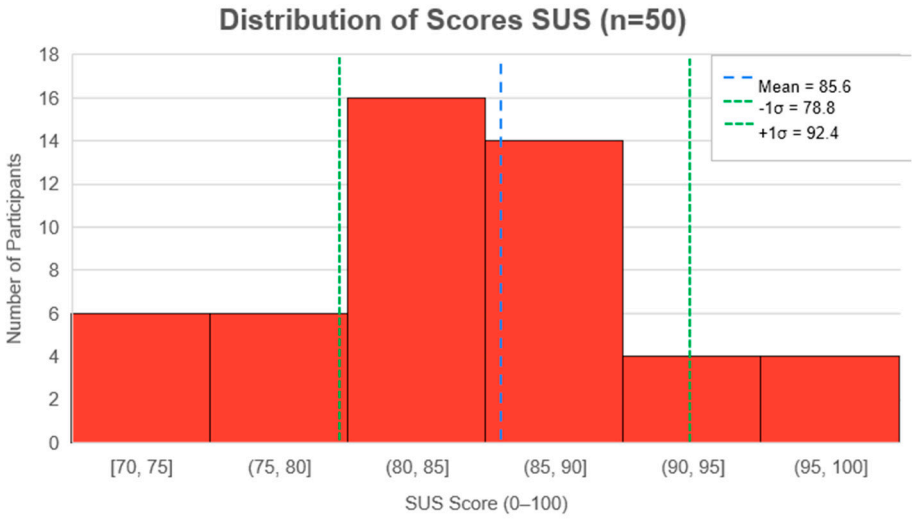

Figure 31. Average SUS values for usability evaluation of the platform.

The System Usability Scale (SUS) was used to assess the platform's usability quantitatively, yielding a score of 0–100. The following chart shows the average SUS score.

The average SUS score was 85.6, indicating a favourable rating of the platform and confirming strong acceptance and usability.

In addition to functional tests, specific accessibility tests were conducted using the official tool certified by the Portuguese Government [34]. This tool evaluates compliance with the W3C WCAG 2.1 guidelines, which define best practices for making web content more accessible to people with different types of limitations. The main platform pages were analysed, specifically the home page, login page, facial login page, standard registration page, and facial registration page. The results were highly positive, with accessibility scores

ranging from 8.8 to 10. According to the guidelines, scores above 8 already represent a reasonable degree of compliance.

Despite the strong results, a detailed review of the accessibility reports revealed that most warnings pertained to technical aspects of HTML structure rather than actual user barriers. Among the issues classified as "not acceptable" were alerts about the lack of alternative text for some decorative visual elements and about repeated labels in specific form fields, creating data entry redundancy. These issues do not compromise understanding or navigation but will be corrected in future versions. Warnings were also identified regarding heading hierarchy inconsistencies and duplicated identifiers, both stemming from dynamically generated JavaScript components. On the login and registration pages, some "manual review" warnings noted colour contrast issues on particular buttons, although manual verification confirmed that the values comply with WCAG 2.1 guidelines. In summary, the results demonstrate strong overall compliance, with minor improvements needed to achieve an AA accessibility level.

The results obtained in the platform evaluation of the same pages (Home page, Facial Login and Facial Registration) are presented below:

Home Page: It received a score of 8.8, as shown in Figure 32, with 4 non-acceptable practices and 4 practices requiring manual verification.

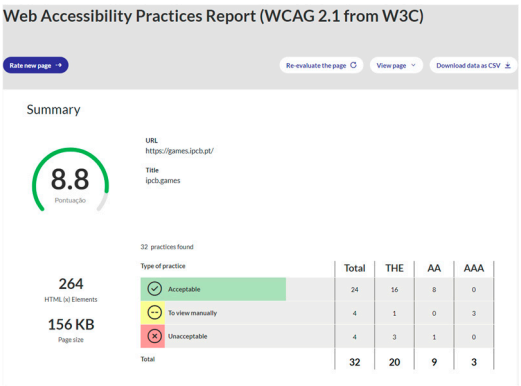

Figure 32. Home Page Accessibility Test.

Login Page: Achieved the maximum score of 10, as illustrated in Figure 33. Only 1 non-acceptable practice and 3 practices requiring manual verification were identified, demonstrating that, despite being a simpler page with fewer elements, it achieved a higher score.

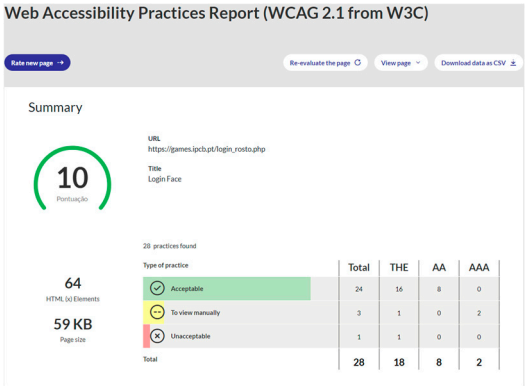

Figure 33. Accessibility Test—Facial Login Page.

Facial Registration Page: Similarly to the Facial Login Page, it also achieved the maximum score, as illustrated in Figure 34.

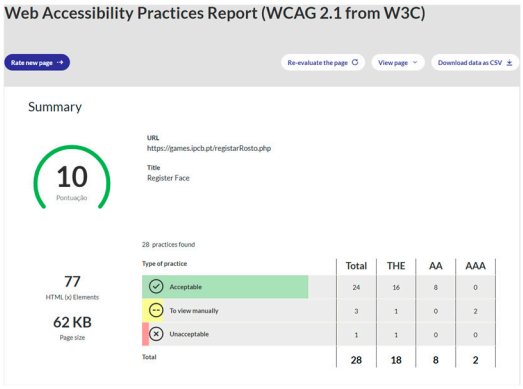

Figure 34. Accessibility Test—Facial Registration Page.

4. Conclusions

This project constitutes a comprehensive process that enabled the development of an inclusive digital platform providing accessible games to all users, regardless of ability. The work was supported by a solid theoretical foundation, based on a systematic literature review using the PRISMA methodology in the fields of digital accessibility, inclusion, and educational platforms, which guided the definition of functionalities and the selection of the most appropriate technologies for platform development. The development phase translated theoretical concepts into practical solutions, with a particular emphasis on implementing features such as voice-based registration and login, facial recognition, a simplified interface, and the ability for users to submit their own games. The adopted multimedia project methodology structured the process into five phases: Analysis and Planning, Design, Production, Testing and Validation, and finally, Distribution and Maintenance.

The technical implementation relied on technologies such as PHP, HTML, CSS, and JavaScript for platform development, Unity for game production, and libraries such as face-api.js and TensorFlow.js for facial recognition. FileZilla and Adminer were used for file and database management.

The Testing and Validation phase, supported by an official tool from the Portuguese Government, enabled evaluation of the platform's accessibility and compliance with WCAG 2.1. In addition to technical testing, real-user evaluations were conducted, whose interactions validated usability and identified future improvements. The Distribution and Maintenance phase began with deploying the platform on an accessible server, already in active use by real users for both game submission and gameplay. This phase will continue through feedback collection, bug fixing, and continuous updates to functionalities, ensuring stable performance and an increasingly inclusive user experience.

In relation to the defined research questions, the results obtained establish a clear and consistent connection between the implemented platform functionalities, the systematic literature review, and the empirical evidence collected throughout the project. Concerning RQ1, the usability tests and the obtained SUS score (85.6) suggest that accessible authentication mechanisms—namely voice-based and facial recognition methods—contributed to increased user autonomy, reduced entry barriers, and facilitated the initial interaction process. These findings indicate that such mechanisms can support digital inclusion when appropriately designed, aligning with the accessibility gaps and opportunities identified in the literature. Regarding RQ2, the evaluation conducted by teachers indicates that inclusive educational technologies, supported by simplified interfaces, multimodal feedback, and alternative interaction methods, improve perceived usefulness, reduce cognitive effort, and promote more accessible learning experiences. These results provide empirical support for the pedagogical and accessibility principles highlighted in prior studies. Finally, regarding RQ3, the integration and availability of WebGL-based games suggest that serious games

can foster participation, motivation, and engagement among diverse audiences. When developed according to accessibility, usability, and user-centred design principles, accessible digital games reinforce their potential as meaningful tools for inclusion in both educational and recreational contexts.

Beyond the development of the ipcb.games platform, this work contributes research-level insights into the design and evaluation of inclusive digital gaming platforms. The results highlight the importance of addressing accessibility at the initial interaction stages, particularly through accessible authentication mechanisms. The combination of voice-based and facial authentication, sequential interaction, confirmation loops, and continuous multimodal feedback emerged as effective design strategies for reducing cognitive load and improving perceived usability. These findings extend existing accessibility research by demonstrating how inclusive authentication mechanisms can be operationalised and empirically validated within a real-world digital platform, offering transferable design principles applicable to other inclusive digital systems.

For future work, voice-controlled games are planned, and we intend to expand voice commands across all pages to ensure fully accessible navigation. Another goal is to develop a system that enables teachers to manage student groups and track individual and collective statistics, and to implement complementary solutions, such as eye-tracking and keyboard scanning, to ensure access without a mouse.

Finally, continued maintenance will be essential to sustain the platform's evolution as a tool for digital inclusion in both educational and leisure contexts. By providing validated evidence from a real-world deployment, this work complements existing conceptual and guideline-based studies. It contributes to a deeper understanding of how accessible authentication mechanisms can be effectively integrated and evaluated in digital platforms.

Author Contributions: Conceptualization, Methodology, R.M., S.L., Â.O., P.S. and F.F.; Software, R.M. and S.L.; Validation, R.M., S.L., Â.O., P.S. and F.F.; Investigation, R.M., S.L., Â.O., P.S. and F.F.; Resources, R.M., S.L., Â.O., P.S. and F.F.; writing—original draft, R.M. and S.L.; writing—review and editing, R.M., S.L., Â.O., P.S. and F.F.; Supervision, Â.O., P.S. and F.F. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was exempt from Ethics Committee approval under Portuguese law (Law 21/2014 and Law 58/2019) and EU Regulation 2016/679 (GDPR), as it involved minimal-risk research based solely on anonymous questionnaire data, with no collection of personal or sensitive information. The study adhered to the principles of the Declaration of Helsinki and all relevant ethical guidelines.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ACM	Association for Computing Machinery.
API	Application Programming Interface.
CSS	Cascading Style Sheets.
FTP/SFTP	File Transfer Protocol/Secure File Transfer Protocol.
HTML	Hyper Text Markup Language.
IEEE	Institute of Electrical and Electronics Engineers.
MySQL	Structured Query Language.
PHP	Hypertext Preprocessor.
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
SUS	System Usability Scale.
W3C	World Wide Web Consortium.
WCAG	Web Content Accessibility Guidelines.
WebGL	Web Graphics Library.

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