



Development of an Inclusive E-Learning Platform for Visually Impaired Students

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ABSTRACT

This research focuses on developing an inclusive e-learning platform to enhance accessibility for visually impaired students, addressing shortcomings in conventional learning environments. The primary aim is to create an educational space that is more accommodating and supportive of diverse user needs. The platform prioritizes user-friendliness, offering essential features such as language translation and support for multimodal content, including text and video formats. The development process employed the Rapid Application Development (RAD) methodology, enabling iterative prototyping and seamless integration of user feedback. This approach facilitated continuous refinement of the platform to meet real user needs effectively. The design adhered strictly to W3C accessibility guidelines, ensuring compliance with global web accessibility standards. Technologies like HTML, CSS, PHP, and JavaScript were utilized, alongside accessibility testing tools such as non-visual desktop access (NVDA) and WAVE, to ensure a robust and accessible user experience. Key features, including font size and contrast adjustment sliders, were integrated based on user feedback. The results indicate that the platform significantly enhances the accessibility of educational resources, empowering visually impaired students. Its novel combination of RAD methodology and strict adherence to accessibility standards demonstrates a practical and user-centered approach to tackling educational inequities.

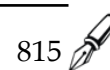


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INTRODUCTION

Virtual Learning Environments (VLEs) are computer-based platforms that enable learners and tutors to engage in various online activities designed to facilitate education and training. They are widely used as tools for instruction and knowledge acquisition, either as standalone systems or in conjunction with traditional classroom-based learning. Furthermore, VLEs serve diverse purposes, including staff training within organizations and governmental bodies (Laeq & Memon, 2018). These platforms have gained significant traction due to their ability to provide access to course materials, facilitate assignment submissions, and enable participation in live or recorded lectures. However, while VLEs employ advanced technologies, they often fall short in catering to the specific needs of visually impaired students, thereby limiting the inclusivity of such platforms (Tyagi et al., 2022).

Virtual reality technologies have enhanced the scope of virtual learning by simulating scenarios inaccessible in real-life settings, making them an effective supplement to traditional teaching methods (Bazhenova et al., 2022). Despite this progress, the lack of accessibility features,



such as voice feedback and spoken commands, poses significant barriers for visually impaired learners. Students with disabilities, such as dyslexia, dyscalculia, or visual impairments, face substantial challenges in higher education due to inadequate technological support, including insufficient compatibility with screen readers and magnifiers (Mahmud et al., 2020). This digital divide highlights the disparity between the potential of VLEs and their actual effectiveness for all users.

Although several measures have been implemented to improve accessibility for individuals with disabilities, such as ramps, wheelchair access, and support workers, these efforts have not fully addressed the challenges of digital inclusion (Sahoo & Choudhury, 2023). Visually impaired students often require alternative materials, such as audio recordings of lectures or text-based transcripts, to access educational content. However, these resources are not always readily available or affordable, further exacerbating the difficulties faced by this group (Gill et al., 2017). Moreover, the user interfaces of many e-learning platforms are overly complex, making navigation challenging for visually impaired users (Ngubane-Mokiwa & Khoza, 2021). Inconsistent accessibility standards and limited compatibility with assistive technologies further hinder the effectiveness of these platforms (Almomani et al., 2020).

To bridge the gap between the expectations of inclusivity in e-learning and the current reality, it is imperative to prioritise accessibility in the design and implementation of VLEs. This involves addressing the limited efficacy of existing assistive technologies, creating cost-effective solutions, and incorporating disability-specific requirements into the development of e-learning systems. The gradual integration of disabled students into higher levels of education is essential for achieving inclusive growth and ensuring their full participation in society.

This research is underpinned by the theoretical framework of Universal Design for Learning (UDL), which emphasizes creating flexible learning environments that accommodate individual learning differences. UDL principles advocate for multiple means of engagement, representation, and expression, which align with the goal of developing an inclusive e-learning platform. Additionally, this study builds upon the Web Content Accessibility Guidelines (WCAG) established by the World Wide Web Consortium (W3C), ensuring adherence to global accessibility standards.

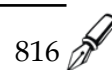
Case studies of successful implementations, such as the use of screen readers and voice-activated technologies in educational contexts, will inform the platform's design. The research will also explore policies and best practices in accessibility, such as those outlined in the United Nations Convention on the Rights of Persons with Disabilities (CRPD), to ensure the platform aligns with international commitments to inclusivity.

Methodologically, the research will adopt a user-centered design approach, incorporating feedback from visually impaired students and experts in assistive technology throughout the development process. Prototyping and iterative testing will ensure that the platform's features meet user needs effectively. Tools such as NVDA (NonVisual Desktop Access) and WAVE (Web Accessibility Evaluation Tool) will be employed to evaluate accessibility compliance during the development cycle.

The main contributions of this research are to:

1. Identify and address the limitations of current assistive technologies in supporting visually impaired learners.
2. Design cost-effective and universally accessible solutions to ensure inclusivity.
3. Integrate accessibility features, such as voice feedback and intuitive navigation, into e-learning systems.
4. Adhere to and promote consistent accessibility standards across e-learning platforms.

By addressing these objectives, this research seeks to close the gap between the current state of VLEs and the goal of creating a fully inclusive digital learning environment, ensuring equitable access to education for visually impaired students.



LITERATURE REVIEW

Digital Accessibility Challenges

Digital accessibility challenges within virtual learning environments pose significant hurdles for disabled students, particularly those with visual impairments. Despite efforts to create inclusive educational platforms, there are persistent gaps that hinder the seamless integration of disabled students into online learning. According to Gin (2020) the lack of standardized accessibility features in many virtual learning environments exacerbates the difficulties faced by students with disabilities. Furthermore, research by Paranal III (2020) emphasizes the impact of non-compliance with accessibility standards on the educational experiences of visually impaired students. The absence of universally designed interfaces and content often leads to frustration and limited participation in online learning activities. These challenges highlight the urgent need for comprehensive strategies to address digital accessibility gaps in virtual learning environments. In the context of digital accessibility, the Web Content Accessibility Guidelines (WCAG) recommends incorporating features such as text alternatives, keyboard navigation, and compatibility with assistive technologies for creating an inclusive online learning environment (Daoust, 2018).

Shaheen and Lohnes Watulak (2019) conducted a review that analyzed the accessibility of technology in K-12 schools in the United States. Their study emphasized the disparities experienced by impaired students in technology-driven learning settings. In spite of the existence of federal and state accessibility laws, there is still a widespread presence of technologies that are not accessible in K-12 education. The authors contend that ensuring equitable access to technology is a matter of fairness that should be given high priority in discussions and implementation of instructional technology in order to tackle this imbalance.

Assistive Technologies in E-Learning

The role of assistive technologies in e-learning is crucial for enhancing the educational experiences of disabled students, particularly those with visual impairments. Assistive technologies aim to bridge the accessibility gaps and empower students to engage with online learning content effectively. Research by Enríquez (2024) underscores the significance of assistive technologies in providing tailored solutions for students with diverse needs. Screen readers, magnification tools, and voice recognition software are among the assistive technologies that offer personalized support, enabling visually impaired students to navigate digital content with greater ease (Oyekunle et al., 2020).

However, challenges persist regarding the availability and affordability of these technologies. According to a study by Fichten (2009), some disabled students face financial constraints in accessing necessary assistive tools, limiting their ability to fully participate in e-learning. This raises concerns about the equitable distribution of resources to ensure that all students, regardless of their abilities, can benefit from assistive technologies. To address these issues, it is essential to advocate for the integration of assistive technologies in the design phase of e-learning platforms. Institutions should prioritize the development of disability-aware e-learning systems that not only accommodate different impairments but also consider the financial constraints of students (Nahar et al., 2015). Additionally, collaborative efforts between educational institutions, technology developers, and policymakers are needed to establish affordable and widely accessible assistive technology solutions for disabled students.

Enhancing Educational Accessibility through Technology

Technological progress has significantly improved access to education, making learning more accessible and adaptable for a variety of learners. Students with impairments can access instructional content and participate in learning activities more successfully with assistive technologies including screen readers, speech-to-text software, and captioning tools (Farhan & Razmak, 2022). Moreover, the increase in online educational platforms and resources has



broadened access to education, allowing students to learn at their own speed and in their preferred setting.

Various success stories and case studies showcase the beneficial effects of accessible educational platforms. Screen readers and text-to-speech software allow visually challenged students to access digital textbooks and internet resources, improving their learning experience. Captioning tools have enhanced accessibility of video content for students who are deaf or hard of hearing, enabling them to fully participate in educational videos and lectures (Wearmouth & Butler, 2021). Current initiatives in improving educational accessibility through technology involve the creation of sophisticated assistive technologies, like AI-driven captioning and translation systems. These technologies offer real-time captioning and translation, enhancing accessibility for students with various requirements. The incorporation of virtual reality (VR) and augmented reality (AR) in education can provide immersive and easily accessible learning experiences. This enables students to better understand complicated topics and engage with content in innovative ways. In the future, advancements in educational accessibility through technology will focus on improving personalised learning tools and adaptable technologies. These technologies can accommodate individual learning needs and preferences, guaranteeing that all students have equitable chances to excel. Collaborations among educators, technologists, and accessibility specialists are important for driving innovation and ensuring that technology remains a transformative force in enhancing the accessibility of education for all individuals.

User Experience and Adoption in Inclusive Learning Platforms

Ensuring optimal user experience (UX) in inclusive learning platforms is essential to enable all students, regardless of their ability, to access and engage with educational content successfully. Studying user experiences in inclusive learning environments requires examining user interactions with the platform and pinpointing areas for enhancement to improve accessibility and usability. Akugizibwe and Ahn (2020) reviewed key factors affecting user adoption of accessible educational platforms and found that the platform's user-friendliness, the presence of pertinent and captivating material, and the efficiency of integrated assistive technologies are key. Platforms with a fluid and intuitive user experience are more likely to be embraced by users, as they allow learners to simply traverse the platform and concentrate on learning (Balogun et al., 2022).

Continuous improvement tactics for inclusive learning systems might rely on user input and engagement statistics (Aldowah et al., 2019). Collecting input from users, such as students, educators, and accessibility specialists, can offer valuable perspectives on how to improve the platform to cater more effectively to a variety of learners. Studying engagement data, including usage trends and user interactions, helps pinpoint areas for enhancing user experience and encouraging adoption. Developers may maintain the relevance and effectiveness of inclusive learning platforms by consistently refining and enhancing the platform using user input and engagement data. Encouraging a user-centered design culture and prioritizing accessibility within the development team may guarantee that accessibility factors are incorporated into all stages of the platform's design and development (Basri et al., 2020).

Interactions between users with visual impairments and haptic technology

Visual impairment refers to the limitation in the functioning of the eye(s) or the vision system. It is a variety of disorders that can include decreased visual clarity or range, double vision, difficulties with perception, and visual distortion. The World Health Organization classified people who have difficulty seeing into two main types of visual impairment: low vision or blindness. Poor vision, as defined by the Centre for Disease Control and Prevention (CDC), refers to a visual acuity that falls between the range of 20/70 to 20/400 in the eye with improved vision, even when corrective glasses or contacts are used (Jackson et al., 2023). Alternatively, it can be characterized as possessing a vision field that is equal to or smaller than 20 degrees. Blindness on the other hand is defined as having a visual acuity of 20/400 or worse in the eye with improved



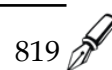
vision, even with the use of glasses or contact lenses, or having a visual field of 10 degrees or less, and diabetic retinopathy, a condition arising from diabetes, is the primary cause of blindness (Kropp et al., 2023). Age-related macular degeneration (AMD), a condition affecting the eyes that is linked to the aging process, together with cataracts (clouding of the lens of the eye) and glaucoma (a disease that harms the optic nerves), are prevalent factors contributing to vision impairment (Nowak & Smigielski, 2015).

However, Human-computer interaction (HCI) is a discipline that focuses on the design, evaluation, and implementation of computer systems for human users. Human-Computer Interaction (HCI) studies the interaction between humans and machines, with a specific emphasis on the link between the two. People who have visual impairments use haptic technology to interact with a virtual environment and interact with virtual haptic widgets. Azofeifa et al. (2022) presented a framework for multimodal interaction specifically focused on haptic technology. The model comprises a user, an interaction model, a physical interface, and an environment. The interaction model precisely delineates the correlation between several sensory inputs and surroundings. Multimodal sensory inputs encompass the consolidated information derived from different sensory modalities, such as tactile and auditory stimuli. Kim and Schneider (2020) identified four essential interactions between haptic technology and a user. The interactions consist of navigating the virtual environment, locating items and getting an overview, comprehending object features, and distinguishing between objects. For easier navigation in the virtual environment, a corner of the workspace should be designated as a reference point.

E-Learning and Visually Impaired Learners

E-learning involves a diverse range of media and technology. E-learning can be defined by multiple interpretations (Alenezi, 2020). Some definitions are inclusive, embracing all forms of structured contact between individuals utilizing computers or networks as the medium of communication, while others are more precise, delineating the process of instruction and acquisition that predominantly occur through computer-based resources on the web, encompassing hyperlinks and/or the Internet, as well as real-time and/or delayed communication (Kannadhasan et al., 2020). In this study, E-learning is defined as the distribution of a learning, training, or educational program through electronic means. This includes various applications and processes such as web-based learning, computer-based learning, virtual classrooms, and digital collaboration (Martinez-Garcia et al., 2023).

Multiple research studies suggest that despite significant advancements in technology accessibility, visually impaired learners still face difficulties with inadequately designed computer interfaces that lack certain web design features. It is noted that most adaptive technologies utilized by visually impaired individuals only assist them in navigating the Internet in a sequential and linear manner (Kandalan & Namuduri, 2020). However, web designs are now more frequently integrating Java-based hypermedia and multimedia components alongside diverse advanced visual features like graphics, hyperlinks, and pop-up windows (Mwanza et al., 2021). The conflicts arising from the linear navigation of adaptive software and the prevalence of non-linear web designs impose constraints on visually impaired (VI) users, hindering their ability to acquire and utilize information (Riley-Ancar, 2022). Consequently, VI users are occasionally compelled to discontinue their educational endeavors. Meanwhile, the majority of individuals involved in creating web content, such as developers, authors, and designers, make an effort to adhere to the accessibility and usability criteria set forth by the World Wide Web Consortium. These guidelines, established by the Web Accessibility Initiative in 1999, include recommended practices to ensure that web content is accessible to all users (Campoverde-Molina et al., 2020). Web accessibility is prioritized over usability considerations for individuals with disabilities. Accessibility and usability are closely interconnected ideas, while accessibility primarily concerns ensuring that a website is accessible to a broader range of users, usability focuses on enhancing users' experiences by making their interactions with the website more efficient and gratifying. Designers frequently focus solely on addressing accessibility difficulties when considering



individuals with special needs, neglecting the equally significant usability aspect of e-learning tools (Stelford, 2023).

Accessibility of VLEs

The VLE is not a new concept, as its utilisation has endured for more than a decade. VLEs have the potential to foster profound learning experiences characterised by social interaction, active participation, contextual relevance, high levels of engagement, and student autonomy (Mystakidis, 2019). VLEs can facilitate the acquisition of lifelong learning abilities. The success of these tools relies on the teachers' ability to select the suitable characteristics and modify them to align with their pedagogical approach and teaching methodology. There is strong evidence that a Virtual Learning Environment (VLE) has the potential to enable learners to engage in autonomous learning (Khlaisang & Songkram, 2019). However, the realisation of this potential depends on several aspects, such as the precise type of activity used, the quality of instructor assistance, the learning environment, and students' individual perceptions.

Blind students rely on screen readers to access electronic media, whereas students with low vision can employ customizing choices and optical aids to improve accessibility to different software applications, including those with graphical interfaces. Visually impaired students have multiple challenges that can be alleviated by ensuring that the institution's VLE is accessible for users of screen readers. Blind students face difficulties in using VLEs that heavily rely on visual multimedia due to the inadequate performance of screen reading facilities with graphics-intensive screens. Web accessibility pertains to the creation and construction of websites, web-based apps, and technology in a way that allows those with disabilities to effectively utilize them. More specifically, individuals possess the capacity to perceive, understand, navigate, and interact with the Internet. Enhanced accessibility also enables persons without disabilities to better utilize software and websites. Various types of keyboards, such as QWERTY keyboards, embossed and engraved keyboards, as well as braille digital displays and braille typewriters, are beneficial for creating braille documents for visually impaired individuals (Adler, 2023). However, it is important to note that students and learners with visual impairment have diverse needs due to the wide range of visual impairments. To address these accessibility needs, several tools and methods have been identified, including screen reading software, screen enlargement or magnifier software, and support for movable menus and keyboard-driven functionality.

Batanero-Ochaíta (2021) assesses the accessibility and usability of a learning platform designed for students with diverse abilities, including those who are deaf and blind. The study examines the perspectives and dispositions of visually impaired and hearing-impaired students toward the utilization of a modified educational platform. The results suggest that although both groups possess a favorable disposition towards the adaption, there exist disparities in their perception of the simplicity of utilization and availability of educational materials. The study emphasizes the significance of customizing learning platforms to cater to the requirements of students with varying abilities, with a particular focus on the influence of these customizations on the accessibility and usability of the platforms. (Costa et al., 2022) provides a concrete illustration of how educational institutions might enhance the accessibility of VLEs and instructional resources. The study presents a methodology for defining and executing accessibility needs in order to minimize barriers to accessibility in VLEs. The results underscore the significance of software engineering teams in enhancing the accessibility of VLEs and educational materials. This underscores the ongoing necessity to improve accessibility standards in online education.

User Interface Design for Accessibility

Designing the User Interface (UI) for Accessibility has become essential to make educational platforms inclusive and accessible to all users, especially those with visual impairments (Gilbert, 2019). The principles involve aspects like clear navigation, ensuring content is perceivable and operable, and allowing flexibility in user interface interaction. These techniques involve



implementing features like screen reader compatibility, keyboard navigation, and high contrast images. Designers should also include alternate language for photos, use descriptive labels for form fields, and maintain a logical and consistent layout (Mahamad et al., 2022). Adhering to accessibility standards and rules is essential to cater for the requirements of users with visual impairments on educational platforms. The Web Content Accessibility Guidelines (WCAG) provide standards for creating accessible interfaces, with detailed instructions for text alternatives, keyboard accessibility, and layout design (Kumar et al., 2021).

Chen (2020) proposed that educational platforms may improve accessibility and enhance the learning experience for students and instructors globally by using language translation features and effective tools and strategies. Schreihans (2019) introduces a four-step pedagogical process called "360-Degree Accessibility" for improving accessibility in higher education's e-learning courses. The process aims to enhance success for disabled students, particularly those with visual and auditory impairments. It emphasizes the importance of creating an inclusive e-learning environment through equal opportunity and reasonable accommodation. The study provides examples and guidelines for implementing the process, highlighting its benefits for students' social awareness and responsibility.

METHODOLOGY

The software development model adopted in this study is the Rapid Application Development (RAD), which is a dynamic software development approach that emphasizes speed and flexibility (Al-Saqqa et al., 2020). The design was divided into multiple phases, with each phase focusing on developing a specific feature or component of the platform. This allowed for continuous refinement and enhancement based on ongoing evaluations. This iterative approach ensured that the platform evolved based on real user needs and feedback, rather than hypothetical requirements (Basri et al., 2023). At each iteration, feedback from visually impaired users and other stakeholders was actively sought. This feedback was crucial in refining features such as the user interface, font and contrast sliders, and language translation tools, ensuring they met the users' needs. The constant involvement of users helped in creating a more user-friendly and accessible platform.

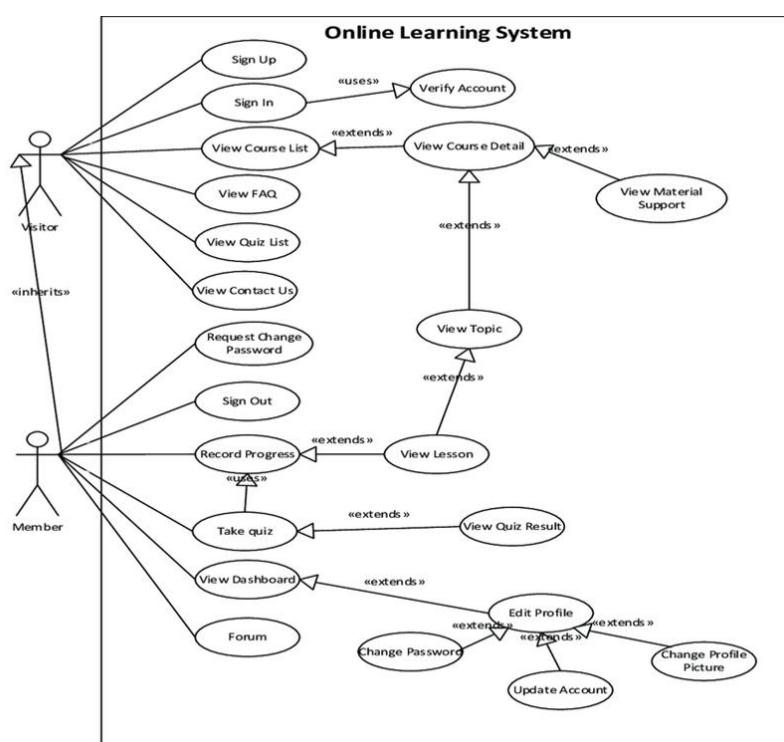


Figure 1. Use-case diagram of the proposed system



To visualize the user interaction and system processes within the e-learning platform, a use-case diagram of the developed system and two comprehensive flowcharts were created and presented in Figures 1, 2, and 3 respectively. Particularly, these flowcharts illustrate the step-by-step actions taken by the users (students and instructors/lecturers) when interacting with the system. The flowcharts detail user actions, system responses, and decision points.

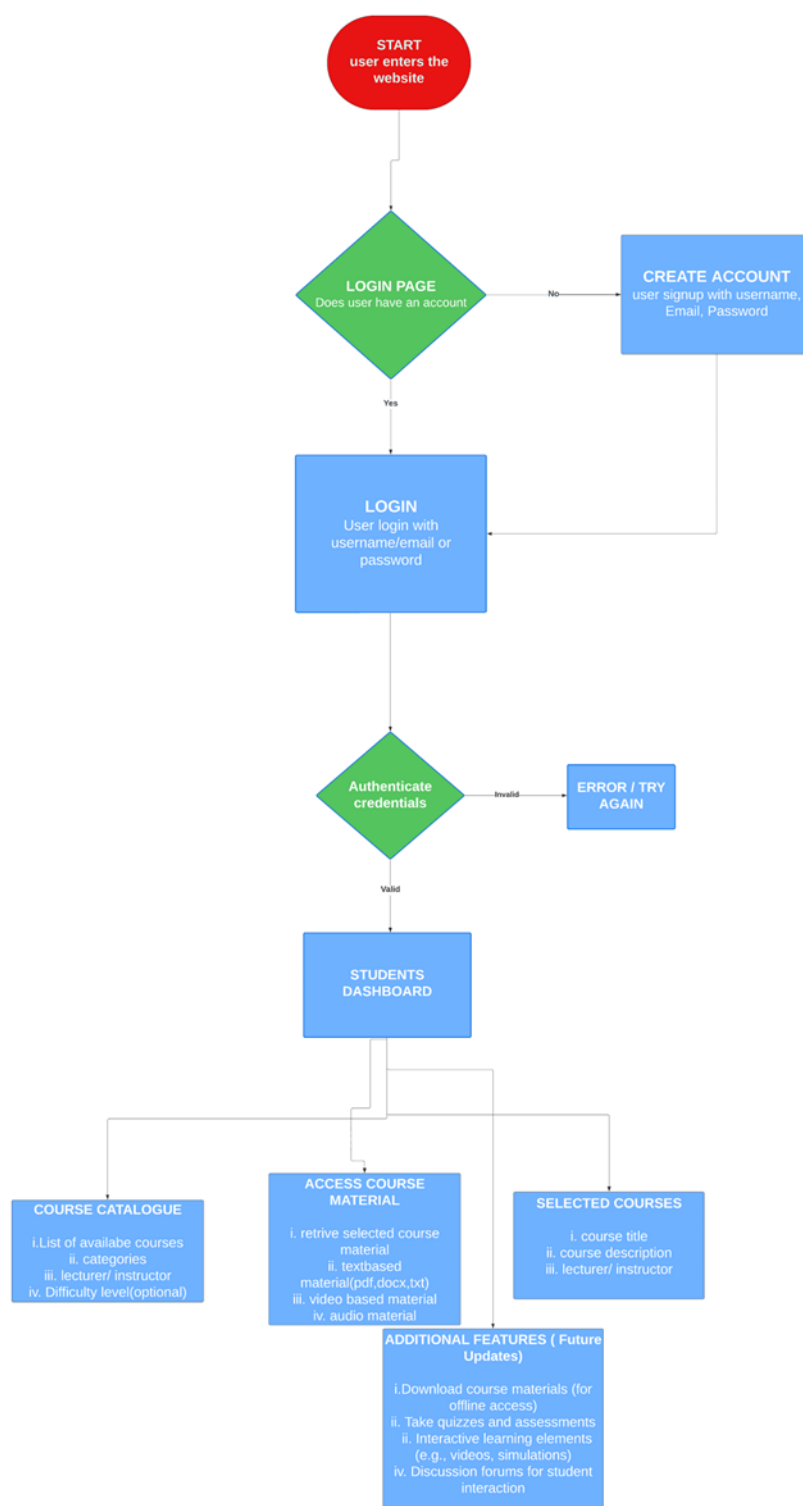


Figure 2. User-flow diagram for students



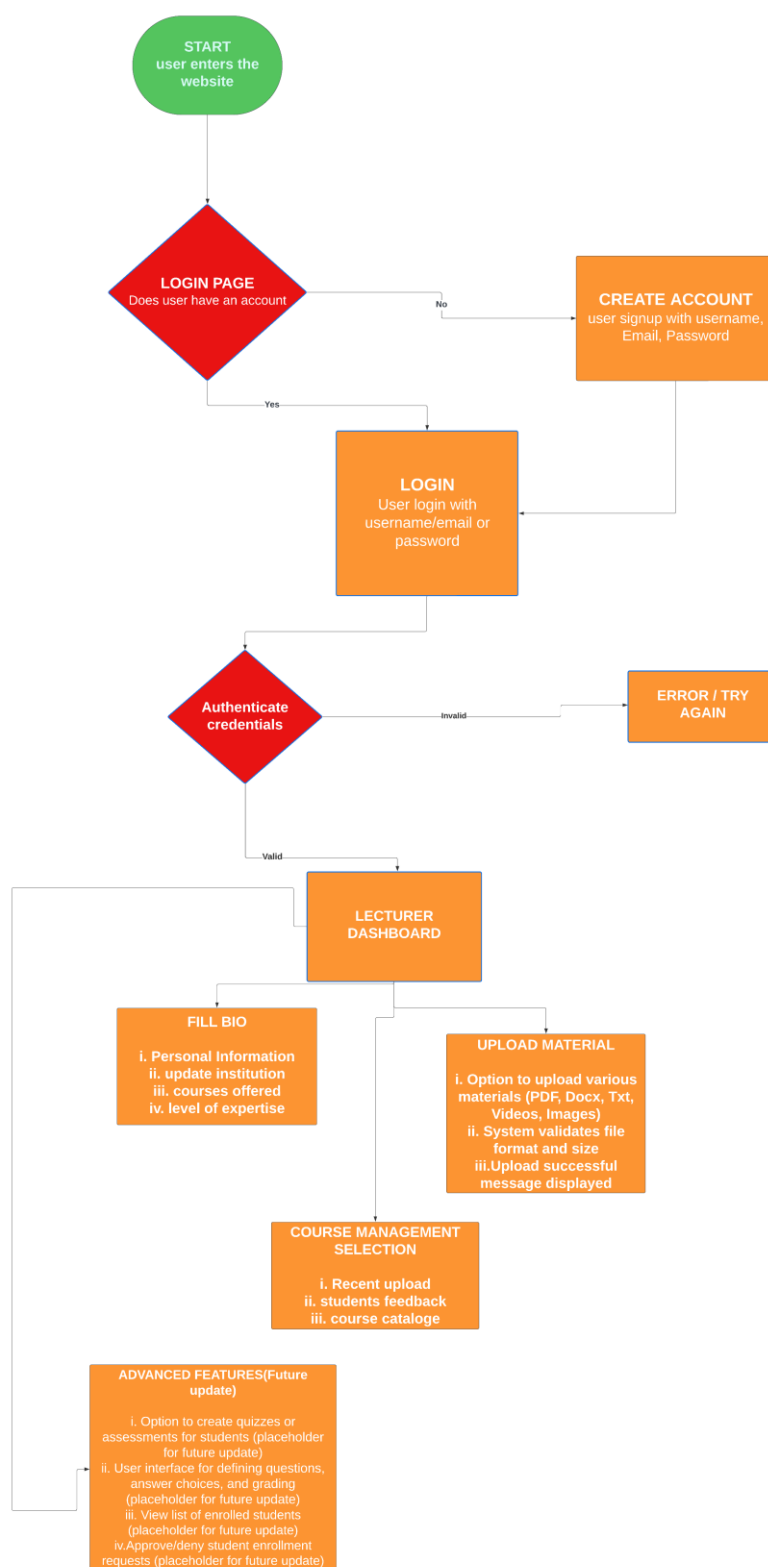


Figure 3. User-flow diagram for lecturers/instructors

SYSTEM DEVELOPMENT AND EVALUATION

The key tools and technologies used to develop the e-learning website to ensure a user-friendly, scalable, and secure platform include Adobe Illustrator and Figma used for designing the website's user interface (UI) and user experience (UX), HTML/CSS, and JavaScript used to develop the website's interactive elements displayed in the user's browser and PHP and MySQL



used to manage the server-side logic, data storage, and application functionalities. The resources utilized are libraries and Application programming interfaces (APIs). The system's requirements specification delineates the desired functionalities, attributes, and features that the system should offer to fulfill the requirements of its users and stakeholders. The language translation features enable users to translate course materials into different languages making the platform more accessible to students from diverse linguistic backgrounds and allowing them to study in their preferred language. Support for various content formats such as text, audio, and video accommodates diverse learning preferences and allows users to access course materials in formats that suit their learning needs, enhancing the overall user experience. Features such as high contrast, keyboard navigation, and screen reader compatibility to enhance usability and accessibility and to give visually impaired students equal opportunities to access educational resources were incorporated. The input specifications include user registration information, course enrolment information, content upload, and accessibility preferences. Output specifications include course content display, user profile information, interactive features, and accessibility features.

The onboarding process includes the landing, sign-up, and login pages, as shown in Figures 4, 5, and 6, which are optimized for screen readers and allow users to create and access their accounts effortlessly. A critical aspect of the user interface design is the inclusion of customizable accessibility features such as font size and contrast sliders. These sliders allow users to adjust the text size and contrast levels according to their personal preferences, improving readability and comfort. The platform offers language translation capabilities that allow users to select their preferred language, ensuring course materials and the user interface are accessible to all students regardless of their linguistic background. The platform also supports a variety of content formats, including text documents, audio files, and video presentations. This flexibility allows educators to upload and share course materials in the most effective format for their content, catering to different learning styles and preferences.

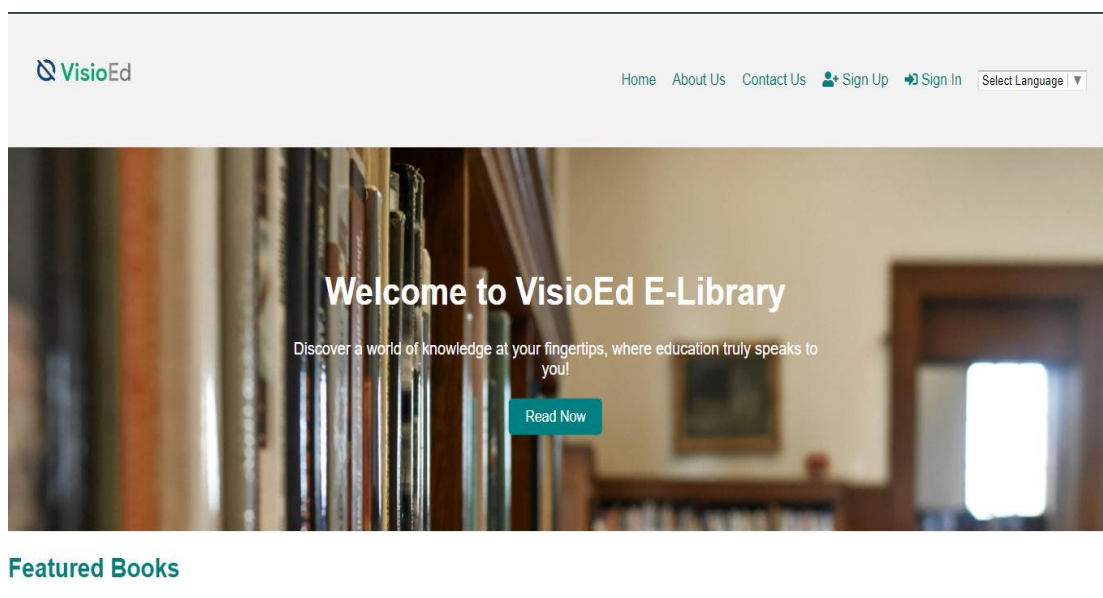


Figure 4. Landing page

The sign-up page as displayed in Figure 5 includes fields for entering personal details, selecting user preferences, and agreeing to terms and conditions. Each field is labeled clearly and is compatible with screen readers to ensure users can navigate and complete the form without any barriers. Similarly, the login page allows users to enter their credentials to access the platform.



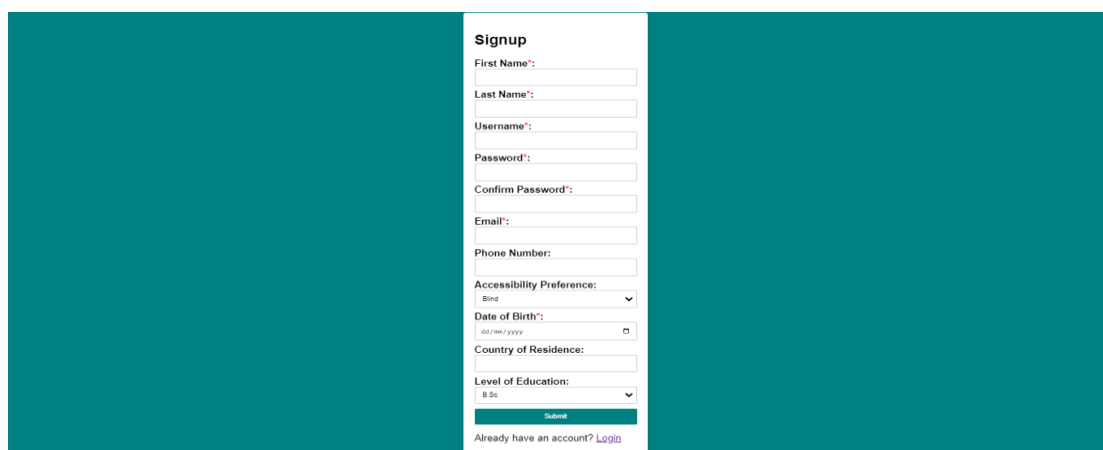


Figure 5. Sign-up page

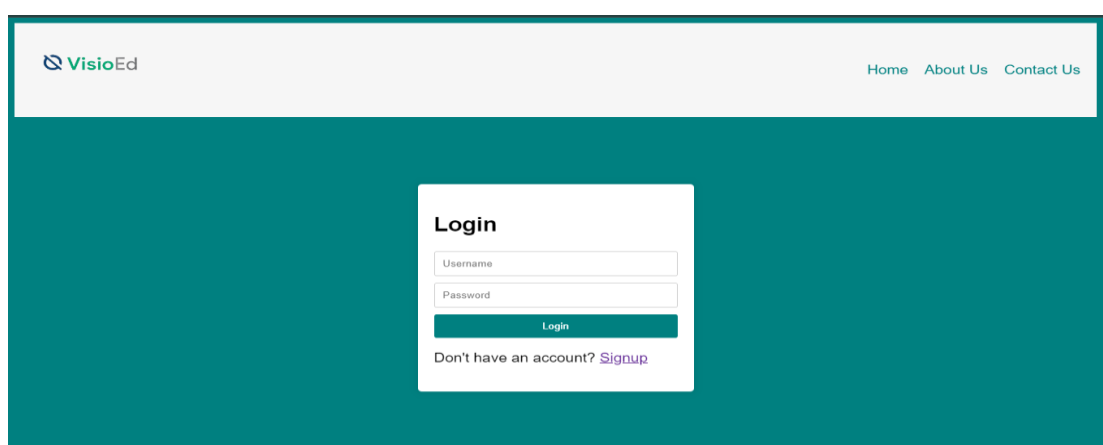


Figure 6. Login page

The user interface design as presented in Figures 7 and 8 focuses on simplicity and clarity, ensuring that visually impaired students can navigate the platform with ease. A critical aspect of this design is the inclusion of customizable accessibility features such as font size and contrast sliders. These sliders allow users to adjust the text size and contrast levels according to their personal preferences, improving readability and comfort.

Accessibility Settings

If you are totally blind, kindly scroll down to the end of the page and click "Next"

Adjust Contrast:



Adjust Font Size:



Apply Settings

Next

Figure 7. Accessibility preference page

The platform supports a variety of content formats, including text documents, audio files, and video presentations. This flexibility allows educators to upload and share course materials in the most effective format, catering to different learning styles and preferences.

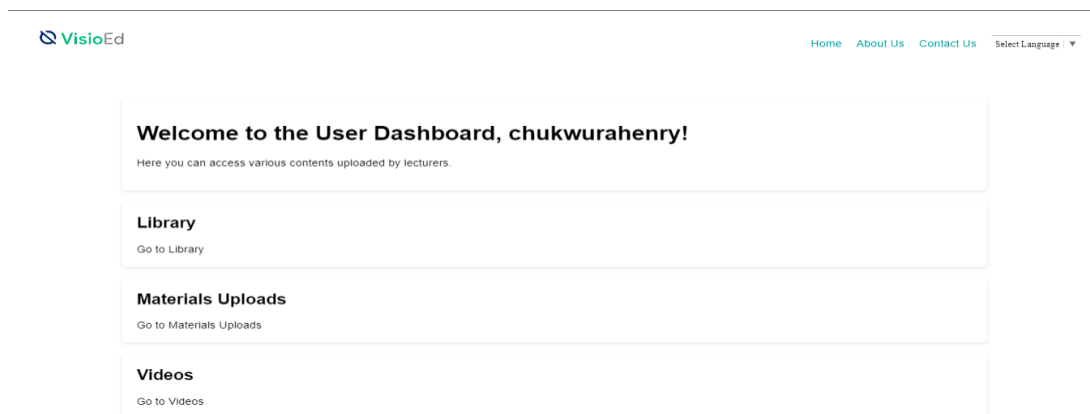


Figure 8. User dashboard

To find out if the system meets the proposed requirements in terms of usability and accessibility, three visually impaired students were asked to use the platform and respond to some questions afterwards as depicted in Table 1. The outcome of the evaluation shows that the users who made use of the system responded positively, thus it can be concluded that the system met the predefined user requirement.

For reproducibility, the codes and scripts USD for the development of the proposed system are readily available and accessible in (Chukwura, 2024).

Table 1. Requirement analysis for the proposed system

S/N	Requirement	User Affected	Test Process	Expected Result	Result
1	A user should be able to register through the system	Student	Users should be able to sign up via required details. The data is collected from the front-end form and saved in the database as a unique entry for each user.	The user successfully registers, and their information is stored in the database.	Passed
2	A user should be able to log in to access all features of the system	Student	Enter login details on the login form. After submitting, the user is authenticated and granted access to their unique view.	The user successfully logs in and accesses their dashboard.	Passed
3	A user should be able to navigate the homepage	Student	Load the homepage and use navigation links to access different sections.	The user successfully navigates to different sections of the homepage.	Passed
4	A user should be able to adjust font size	Student	Use the font size slider to increase or decrease text size.	The font size changes according to the user's selection.	Passed
5	A user should be able to adjust contrast levels	Student	Use the contrast slider to adjust the contrast of the interface.	The contrast changes according to the user's selection.	Passed
6	A user should be able to access course materials	Student	Navigate to the course materials section and access different files.	The user successfully accesses and opens course materials.	Passed

S/N	Requirement	User Affected	Test Process	Expected Result	Result
7	A user should be able to use screen reader compatibility	Student	Use a screen reader to navigate the website.	The screen reader correctly reads out all elements and navigation is smooth.	Passed
8	A user should be able to create a profile	Student	Fill in and submit the profile form.	The user's profile is successfully created and saved.	Passed
9	A user should be able to access multilingual support	Student	Change the language settings to a different language.	The platform's content is displayed in the selected language.	Passed
10	A user should be able to upload course materials in various formats	Instructor	Use the upload feature to add different types of course materials (e.g., PDFs, videos).	The materials are successfully uploaded and accessible to students.	Passed
11	A user should be able to download course materials (text, PDFs, docx)	student	Use the download feature to download text course material.	The material is successfully downloaded	passed

CONCLUSION

The research on VLEs highlights their significant potential for instruction and knowledge acquisition but reveals key barriers that hinder accessibility for visually impaired students. These barriers include complex user interfaces, inconsistent accessibility standards, and limited compatibility with assistive technologies such as screen readers. While VLEs offer various educational functions, they often fail to meet the specific needs of visually impaired students, limiting their inclusivity and effectiveness. The study emphasizes the importance of integrating features like voice feedback, spoken commands, and affordable assistive tools to bridge the digital divide and improve VLE accessibility for all learners.

The fundamental finding of the research is the gap between the potential of VLEs to offer inclusive learning environments and their actual effectiveness for visually impaired students. Despite efforts to enhance accessibility through assistive technologies, challenges such as inconsistent standards, complex interfaces, and inadequate technological support persist. This digital divide underscores the need for better integration of assistive features and adherence to accessibility standards to create truly inclusive learning platforms.

The research has several implications for stakeholders. Educational institutions are encouraged to adopt universal design principles to ensure that VLEs cater to the diverse needs of students, particularly those with disabilities. Policymakers should enforce stricter accessibility standards and promote the development of cost-effective assistive technologies. Software developers are urged to integrate user-centered design practices, prioritize compatibility with assistive tools, and simplify interfaces to enhance accessibility. Addressing these issues will make VLEs more equitable and functional for visually impaired learners, contributing to a more inclusive educational landscape.

Future research directions include exploring the integration of emerging technologies like artificial intelligence and augmented reality to further enhance accessibility features in VLEs. Longitudinal studies assessing the effectiveness of accessible platforms in improving educational outcomes for visually impaired learners would provide valuable insights. Expanding research to include other disabilities and developing cross-platform compatibility could broaden the impact of accessible e-learning solutions. Additionally, investigating the affordability and scalability of



assistive technologies would support the creation of cost-effective solutions for educational institutions with limited resources.

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