Accessible E-learning Platform for the Blind in Low-Cost Platform.

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Abstract

In today's world, while access to information and media is readily available, visually impaired individuals face limitations that result in a lack of learning and entertainment opportunities. To address this disparity, this project aimed to develop an affordable and accessible e-learning website for the blind. The website was chosen for its ease of access and cost-effectiveness and was developed using open-source technologies while adhering to the Web Content Accessibility Guidelines (WCAG 2.0). The platform offers four main functions: an e-learning system, an audiobook library, an online radio station, and a help center. The resulting website achieved AAA level compliance with WCAG 2.0 criteria, signifying a high level of accessibility for all users. The platform is also designed to be scalable and adaptable for future expansion and content updates without significant financial investment. This project successfully created a platform that promotes equality by providing visually impaired individuals with access to information and media. Future development should focus on enhancing compatibility with a wider array of assistive technologies, expanding the e-learning system with advanced features like collaborative learning tools and personalized learning paths, and developing a mobile application to improve accessibility and convenience for users.

Keywords: Web accessibility, WCAG 2.0, E-learning, Blindness

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Introduction

Background

The advancement of technology has made the internet an integral part of daily life. The internet is widely used for convenience, entertainment, and education, leading to new forms of learning media such as electronic media and online applications. Platforms like Facebook, YouTube, and Instagram are used as teaching tools, enabling people to access information and entertainment quickly and widely. However, visually impaired individuals do not have the same level of access to information due to their physical limitations. They primarily rely on auditory senses, and the disparity in access arises from their limited access to learning media, creating inequality. While new learning media that support visually impaired individuals, such as audiobooks and Braille, have emerged, these resources remain limited and have accessibility issues. There is a clear gap in the availability of a single platform that integrates both learning and entertainment functions in an easily accessible and low-cost manner. Therefore, an online learning and entertainment platform that directly supports visually impaired individuals is essential to bridge this gap and promote equality by providing them with access to information

Objective

The project's objective is to bridge the digital divide for visually impaired individuals by developing an accessible and affordable e-learning website. This platform is meticulously designed to dismantle usability barriers and provide a sanctuary of e-learning and entertainment resources. The project's scope includes investigating the specific media needs of visually impaired individuals, developing a user-friendly website tailored to these needs, and conducting rigorous real-world testing to ensure its efficacy and usability.

To achieve these ambitious goals, our scope is comprehensive and meticulously planned. We will delve into the specific electronic learning media needs of visually impaired individuals, exploring their preferred formats and learning styles. Simultaneously, we will scrutinize the existing landscape of online media usage, identifying the precise problems and limitations that impede their full participation. This foundational research will pave the way for an exploration of innovative approaches, seeking to discover and implement cutting-edge techniques for developing websites that are truly accessible. This exploration will culminate

in the design and development of a dedicated e-learning website, tailored to the unique requirements of visually impaired users. Finally, to ensure its efficacy and usability, we will conduct rigorous real-world testing, inviting visually impaired individuals to experience the website firsthand and provide invaluable feedback, ensuring that our creation truly meets their needs and empowers them to thrive in the digital age.

Literature Review

E-learning

The digital age has integrated technology into people's lives and transformed traditional teaching methods into more engaging formats. Learners can easily access education through internet-connected devices, a system known as E-learning.

The term E-learning has two main definitions:

General Definition: Any learning that involves content delivery via electronic devices such as computers, the internet, television, and satellite signals. This includes existing teaching formats like Computer-Assisted Instruction, Web-Based Instruction, Online Learning, and Distance Learning Television.

Specific Definition: Learning content delivered through text, static images, animation, and sound, using web technology for content delivery and Course Management Systems for learning management. This includes tools for communication between instructors and learners, post-tests, learning progress tracking, and student evaluation.

E-learning is a teaching and learning approach that uses computer networks or electronic media for content delivery, which can be one-way or interactive (Welsh et al., 2003, p. 245).

E-learning comprises four key components:

Management Education System: A central system for managing the teaching and learning process, delivering lessons, evaluating outcomes, and controlling and supporting services for learners.

Contents: The instructional content, which must be of high quality and meet the learners' needs to achieve the learning objectives.

Communication: Two-way communication to enhance engagement, such as quizzes during or after lessons, enabling interaction between learners and instructors.

Evaluation: Assessment methods to determine whether learners have achieved the learning objectives, ensuring that E-learning includes learning outcome evaluations.

E-learning Website in Thailand

Thai MOOC: Thai MOOC is an online learning management system developed in collaboration with leading Thai universities. It offers various courses accessible on multiple devices, allowing users to learn anytime and anywhere at their convenience (Chunwijitra et al., 2020, p. 1078).

SET E-learning: SET E-learning provides digital financial and investment knowledge with multimedia and lessons for students and investors seeking to become professional investors. It is developed by the Stock Exchange of Thailand (Rüth & Kaspar, 2017, p. 98). A study on E-learning systems for learner potential development in Bangkok towards international standards surveyed 400 Bangkok learners with E-learning experience using Google Forms. The study found that most learners were highly satisfied with the content structure's coverage of learning objectives, indicating that E-learning enables learners and instructors to access various databases and enhances information access. Learners reported moderate satisfaction with E-learning's support for self-directed learning. Most learners were highly satisfied with E-learning's engaging and diverse learning activities and its modern and accessible learning channel. The study also identified E-learning drawbacks, noting that it limits the ability to perceive learners' true feelings and reactions, and requires learners and instructors to have computer and internet access (Lapcharoen et al., 2018, p. 85).

Accessibility

Definition of Disability

Disability refers to limitations in performing daily activities or participating in social activities due to impairments in vision, hearing, mobility, communication, mind, emotions, behavior, intellect, or learning, combined with obstacles and the need for assistance to engage in daily life or social participation like others (Kaplan, 1999, p. 352).

Blindness

Blindness is the inability to see or perceive the difference between light and darkness. It is a visual impairment that hinders daily life, education, and employment. While some causes of blindness may be untreatable by medication, surgery, or corrective lenses, coping

and prevention strategies exist. Individuals experiencing vision loss should seek immediate medical attention. If vision loss is irreversible, they may need to learn assistive technologies like Braille or screen reader software (Harman, 1926, p. 907).

There are two types of blindness:

1. **Complete Blindness:** Total inability to see anything, perceiving only darkness.
2. **Partial Blindness:** Limited vision, such as seeing only shadows or lacking clear shape recognition.

Learning for Visually Impaired Individuals

Visually impaired individuals cannot learn through traditional visual methods, necessitating curriculum and teaching method adaptations (Adnan et al., 2017, p. 176). Essential learning tools for the blind include:

Braille: A system of raised dots on paper, read by touch.

Residual Vision Utilization: Using enlarged fonts or magnifying glasses for those with partial sight.

Listening Skills: More efficient than Braille, listening is a popular learning method.

Mobility Training: Essential for familiarizing with environments and safe navigation, including the use of guides, guide dogs, or canes.

Assistive Technologies

Web Accessibility

Web accessibility involves designing websites that are accessible and usable by everyone, including the elderly and people with disabilities, based on Universal Design (UD) principles and Web Content Accessibility Guidelines (WCAG) developed by the World Wide Web Consortium (W3C) (Hognestad, 2021).

WCAG 2.0, the current standard developed in 2008, outlines four main principles:

1. Perceivable: Content must be presentable to users in ways they can perceive. For example, providing text alternatives for images enables visually impaired users to understand image details through screen readers.

2. Operable: Users must be able to operate the interface. WCAG standards require keyboard accessibility, allowing users to navigate and interact with content and structure using only a keyboard.

3. Understandable: Information and the operation of the user interface must be understandable. Websites should be user-centered, enabling users to predict content organization. Error messages should include instructions for correction.

4. Robust: Content must be interpretable by a wide range of user agents, including assistive technologies. Current standards rely on Extensible Markup Language (XML) for future adaptability.

WCAG defines three levels of conformance: A, AA, and AAA.

- Level A: Basic accessibility.
- Level AA: Improved accessibility, reducing barriers.
- Level AAA: Excellent accessibility, providing the highest level of accommodation.

Text-to-Speech

Text-to-Speech (TTS), or speech synthesis, converts written text into spoken words. It is a valuable assistive technology for people with disabilities, such as converting text to speech for non-verbal individuals to communicate without sign language. Visually impaired individuals rely on listening to on-screen content, making text-to-speech essential for accessing computer-displayed information (Klatt, 1987, p. 750).

Screen Reader (NVDA)

NonVisual Desktop Access (NVDA) is a free, open-source screen reader for Windows that enables visually impaired users to operate computers. It reads on-screen text using synthesized speech and supports various browsers, applications, and 55 languages. Screen readers help blind users interact with computers by reporting the current cursor position and important information like dialog box alerts (Amin et al., 2024).

ARIA

Accessible Rich Internet Applications (ARIA) is a W3C protocol that enhances user interaction with assistive technologies. It provides semantic meaning to web content, such as page structure, roles for navigation, search, and main content, improving screen reader compatibility. For example, the attribute “aria-hidden=“true”” allows screen readers to skip elements, enhancing navigation (Craig et al., 2009).

HTML5

HTML5 is a markup language used for creating websites, developed from HTML with added features for improved usability.

HTML Structure:

HTML consists of the following basic tags:

1.<!DOCTYPE html>: Declares the document type, enabling web browsers to process the page correctly.

2.<html></html>: Defines the root of an HTML document.

3.<head></head>: Contains meta-information about the HTML document, such as the title (<title></title>) and links to CSS or scripts.

4.<body></body>: Contains the visible page content, including various tags for text, images, video, and audio.

CSS

Cascading Style Sheets (CSS) is a language used to style HTML elements, defining aspects such as background color, font color, display area, and font size. It is used in conjunction with HTML (Gupta & Agarwal, 2022, p. 2264).

There are three ways to implement CSS in HTML:

External Style: CSS rules are defined in separate .css files, which are linked to the HTML document using the <link> tag within the <head> section.

Internal Style: CSS rules are defined within the <style> tag inside the <head> section of an HTML document. These styles apply only to the elements within that specific HTML page.

Inline CSS: Styles are applied directly to individual HTML elements using the style attribute. These styles only affect the specific element to which they are applied.

JavaScript

JavaScript is an object-oriented scripting language used to create dynamic and interactive websites. It is an interpreted language that enhances user interaction and can be used on both the client-side and the server-side. JavaScript enables developers to create more engaging and user-friendly web pages and is widely used due to its open-source nature (Gupta & Agarwal, 2022, p. 2264).

Node.js

Node.js is a cross-platform, open-source, server-side runtime environment and library for developing web applications using JavaScript. It is suitable for data-intensive applications and real-time applications, and it is compatible with various operating systems, including Windows, Linux, Unix, and macOS. Node.js uses the V8 engine, developed by The Chromium Project, to enhance JavaScript performance by compiling the code before execution (Just-in-Time Compilation), enabling JavaScript to run outside of web browsers (Gupta & Agarwal, 2022, p. 2264).

Express

Express is a popular web framework from NPM used for developing Node.js web applications on the backend. It is based on the http module of Node.js and can be used to create web services such as REST APIs. Express includes various NPM modules for handling cookies, sessions, and routing (Gupta & Agarwal, 2022, p. 2264).

React.js

React is a JavaScript library for building user interfaces. It allows developers to create complex UIs by breaking them into smaller, reusable components that function independently (Gupta & Agarwal, 2022, p. 2264).

The core concepts of React include:

1. Components: The basic building blocks of a UI.
2. State: Data contained within a component.
3. Props: Data passed from a parent component to a child component.

MongoDB

MongoDB is an open-source, NoSQL document database. Unlike traditional SQL databases, MongoDB stores data in JSON-like documents with key-value pairs. It is known for its fast read-write operations and is suitable for large, unstructured datasets and real-time applications (Gupta & Agarwal, 2022, p. 2264).

Firebase

Firebase, a Google service, is a real-time NoSQL database for applications and web applications. It offers flexibility and speed, storing data in JSON format. While it uses a table-like structure, it does not have columns, and each row can store various data types, including strings, numbers, arrays, and objects (Gupta & Agarwal, 2022, p. 2264).

React Bootstrap

React Bootstrap is a collection of HTML, CSS, and JavaScript code designed to streamline web development. It provides pre-built components and layout management tools, simplifying and accelerating the development process (Gupta & Agarwal, 2022, p. 2264).

Implementation

This section details the development process of the e-learning website for the visually impaired. It covers the key functions, website structure, database design, frontend-backend communication, and deployment strategies.

The design and testing are based on the actual blind students in primary 6 from The Bangkok school for the blind with test sample of 18 sets during 2022-2023.

Website Functions

The website provides four core functions designed to address the needs of visually impaired users:

E-learning System: This system offers online courses, lesson access, and assessment capabilities. Users can enroll in courses and complete quizzes.

Audiobook Library: This feature provides access to audiobooks. It includes management, search, and upload functionalities for audiobooks.

Online Radio: This function allows users to listen to online radio broadcasts.

Help Center: This resource provides information and support materials specifically for visually impaired users, including news and website usage guides.

Website Structure

The website architecture is organized into the following sections:

Header: Contains the website logo and primary navigation links to E-learning, Audiobooks, Online Radio, and the Help Center.

Content: Displays the main content, which varies depending on the selected function (Figure 1.).

Footer: Includes general website information such as the website name and developer information.

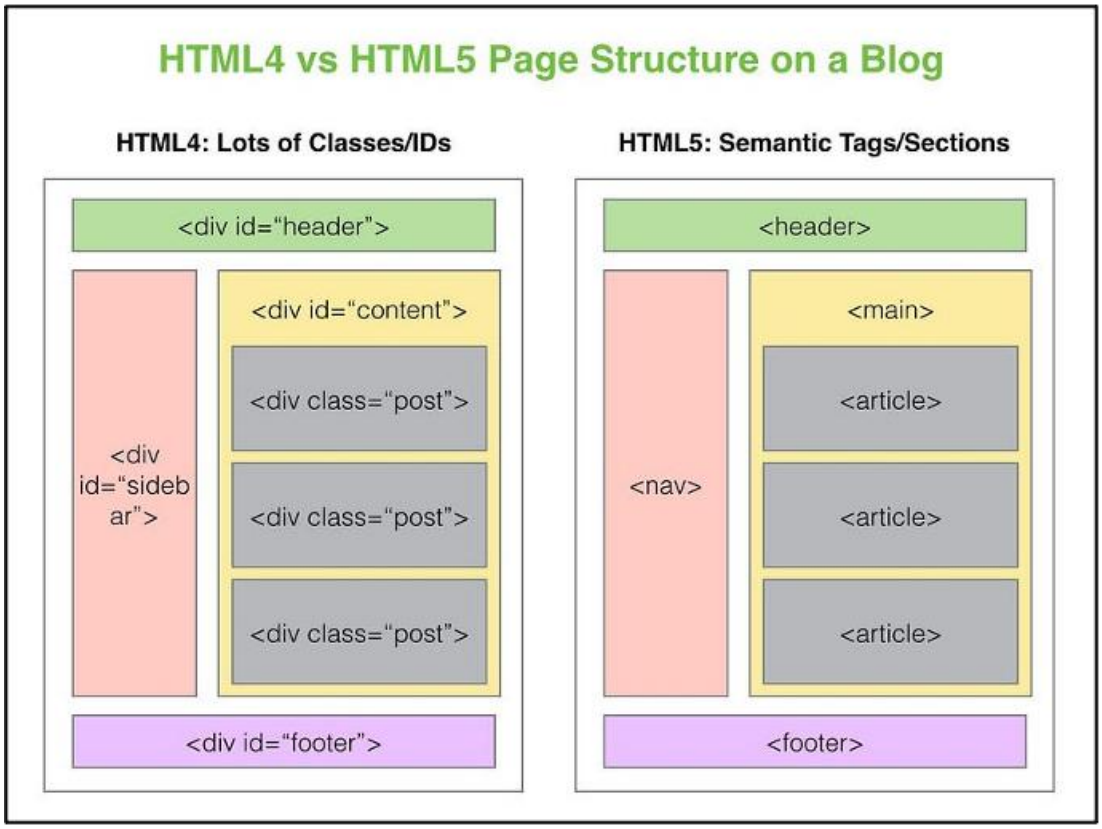

Figure 1 Semantic elements in HTML5

Note. Tpoint Tech (n.d.)

Accessibility Features: Provides tools to enhance accessibility, such as controls for toggling the screen reader, adjusting text size, and enabling high-contrast mode.

Semantic HTML: Semantic HTML tags are employed to clearly define the structure of the website, improving screen reader interpretation.

Focus Indicators: Visual focus indicators are implemented to highlight interactive elements during keyboard navigation.

Database Design

At the core of the website's functionality lies a robust database system, meticulously structured to manage and deliver a wealth of information. Imagine it as a well-organized library, where each section plays a vital role in providing a seamless user experience. The E-learning Database serves as the repository for all educational content, meticulously storing details about courses, individual lessons, and assessments. Here, the learning journey is carefully cataloged and easily accessible. For those seeking auditory enrichment, the Audiobook Database acts as a dedicated archive, housing comprehensive information about each audiobook (as depicted in Figure 2). The User Database, the heart of user interaction, securely manages user account information, ensuring a personalized and secure experience. Beyond structured data, the website also leverages Firebase Storage, a powerful file storage solution, to house a diverse range of media. This digital vault securely stores video content and a collection of images (as seen in Figure 3), enhancing the website's multimedia capabilities and enriching the user experience. Together, these components form a cohesive data architecture, ensuring the website's information is both accessible and well-managed.

This project endeavors to bridge the gap in media access for visually impaired individuals by first understanding their unique media-related problems and needs, then developing a website that addresses usability limitations, provides enriched e-learning resources, offers a user-friendly entertainment platform, and creates a volunteer assistance system; this will be achieved through investigating electronic learning media needs, studying online media usage limitations, exploring accessible website development approaches, designing and developing an e-learning website, and conducting real-world testing with visually impaired users.

```
_id: ObjectId('643ea25269a592b4acab712a')
name: "Rabbit and Turtle"
desc: "Once upon a time a Tortoise and a Rabbit had an argument about who was…"
category: "Tales"
owner_id: "6431ca89180801270375b883"
owner_name: "rain"
▾ chapters: Array
  ▾ 0: Object
      id: 1
      title: "Rabbit invite turtle to race."
      video: "https://firebasestorage.googleapis.com/v0/b/e-learning-for-the-blind-d…"
      _id: ObjectId('643ea69069a592b4acab7246')
  ▸ 1: Object
  __v: 2
```


Figure 2 Coding for Audio Book

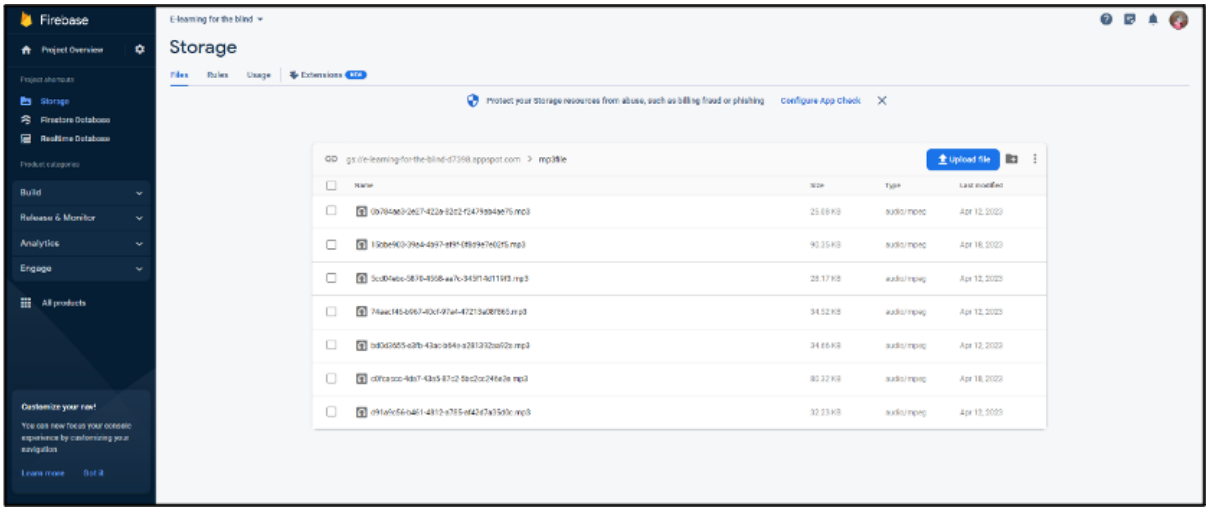

Figure 3 Storage in Firebase

Results and Discussion

This study employed a mixed-methods approach to address the research objectives, consisting of a needs assessment phase and a usability testing phase. For the needs assessment, a purposive sampling method was used to select a group of 18 visually impaired sample sets for in-depth, semi-structured interviews. This protocol was designed to investigate their current online media usage, challenges, and desired features for an accessible e-learning platform. The interview data were subjected to thematic analysis to identify key themes and inform the website's design. In the second phase, a usability and feedback questionnaire were developed to evaluate the completed website. For this, a larger sample of 18 visually impaired sample sets was recruited using convenience or snowball sampling. The questionnaire

included both Likert scale questions to measure user satisfaction quantitatively and open-ended questions for qualitative feedback. This instrument was validated through a pilot test with a smaller group of participants. Quantitative data were analyzed using descriptive statistics (mean, median, and standard deviation), while qualitative data were analyzed using content analysis to refine the website's features and functionality.

This research was conducted in strict adherence to ethical principles governing human subject research. All participants provided informed consent after being fully briefed on the study's purpose, procedures, potential risks, and benefits. Participation was entirely voluntary, and participants were informed of their right to withdraw at any time without penalty. To ensure the confidentiality and anonymity of all participants, data collected were de-identified and stored securely. The study design and methodology were reviewed to ensure the well-being of the participants, upholding the principle of non-maleficence. The research aims to promote equality and accessibility for the visually impaired, thereby ensuring beneficence for this community.

The results of the website development, focusing on web accessibility features and the functionality of each core component.

Benefits of E-learning

1. Enhanced teaching and learning management through Learning Management Systems (LMS), allowing instructors to easily monitor learning outcomes.

2. Self-paced learning, enabling learners to control their learning pace.

3. Interaction between learners and instructors, and among peers, fostering diverse interaction beyond traditional educational institutions.

4. Promotion of new skill acquisition and access to up-to-date content.

5. Reduced content production costs through internet-based learning.

6. Convenient learning anytime and anywhere, accommodating learners' schedules.

Web Accessibility Result from WCAG2.0 evaluation

To achieve web accessibility, simply using the **Web Content Accessibility Guidelines (WCAG 2.0)** as a development framework is insufficient. It is also necessary to verify the website's adherence to these standards. This verification was conducted using an external tool, experte.com, and the test results are passed with excellent with the raw mark are as follows:

URL	Score
/	98
/course	100
/course/create	100
/course/:id	100
/course/edit/:id	100
/course/quiz/:id	100

Web Accessibility Features

The developed website incorporates several key features to ensure accessibility for visually impaired users, aligning with WCAG 2.0 principles.

Semantic Structure and Navigation: The website's structure is defined using semantic HTML tags, providing clear context and facilitating navigation for screen reader users. Tables are implemented with appropriate scope attributes, further enhancing data table navigation for screen readers

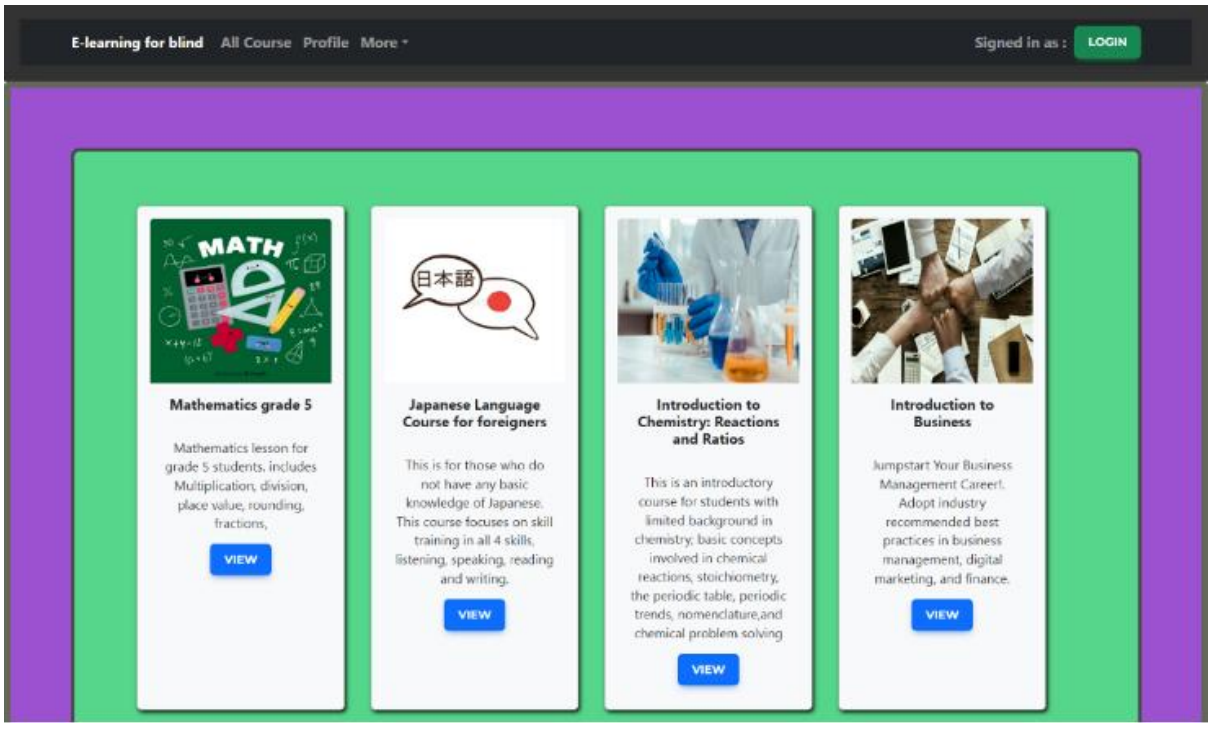

Figure 4 High-contrast color scheme

Visual Accessibility: A high-contrast color scheme is employed to improve readability for users with low vision (Figure 4).

Keyboard Accessibility: The website is designed for full keyboard navigation, enabling users who cannot use a mouse to access all interactive elements and content (Figure 5).

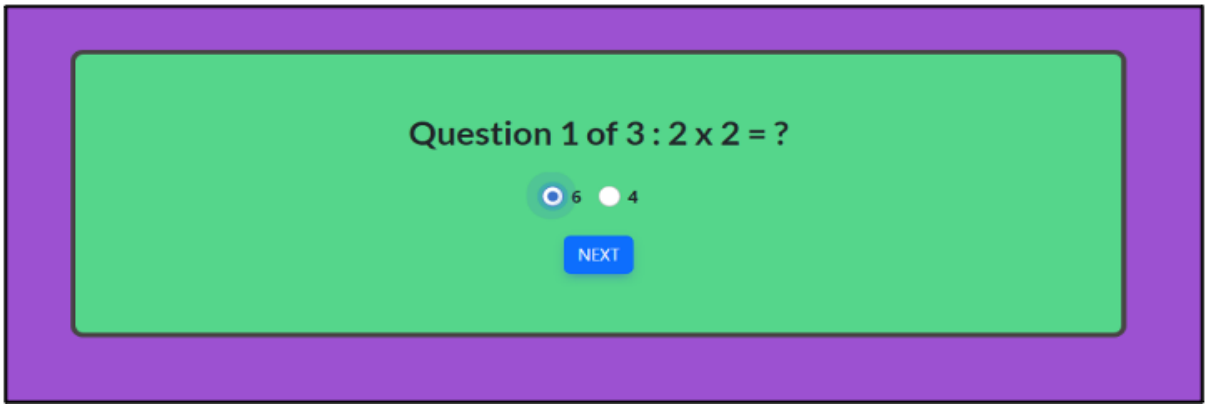

Figure 5 Simplified accessible items.

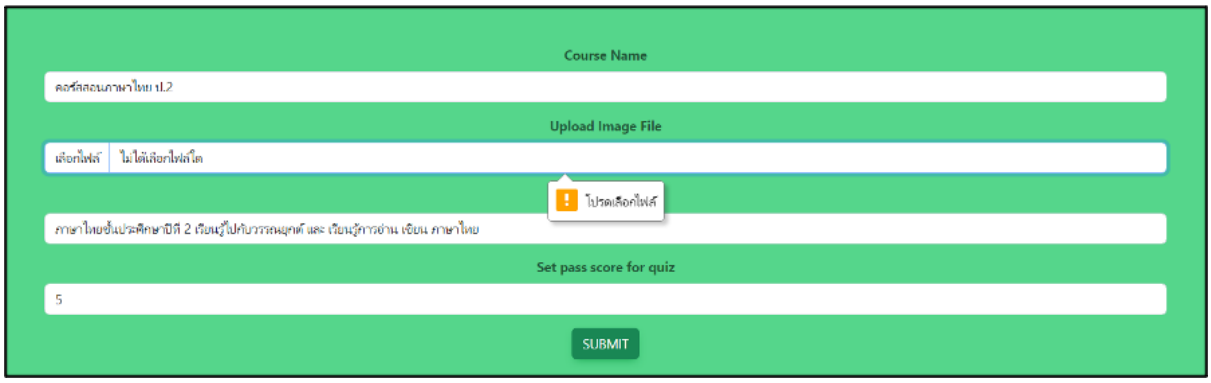

Figure 6 Form, label and error handling with Assistive Compatible.

Assistive Technology Compatibility: The website integrates text-to-speech functionality, allowing users to have content read aloud. Form fields include clear labels to ensure compatibility with screen readers (Figure 6).

User Guidance and Error Handling: The system provides clear error messages and guidance to assist users in correcting input errors.

Focus Management: Distinct focus indicators are implemented to provide visual feedback during keyboard navigation, highlighting the currently active element.

Page Identification: Each page features a descriptive title, aiding screen reader users in understanding the context and purpose of the page.

Screen Reader Optimization: The website's design prioritizes compatibility with screen readers, ensuring that visually impaired users can effectively access and interpret the content.

E-learning System Functionality

The E-learning section provides a comprehensive platform for online learning, catering to both instructors and learners.

Course Management: The system supports the display of available courses, course creation, and course editing (Figure 7).

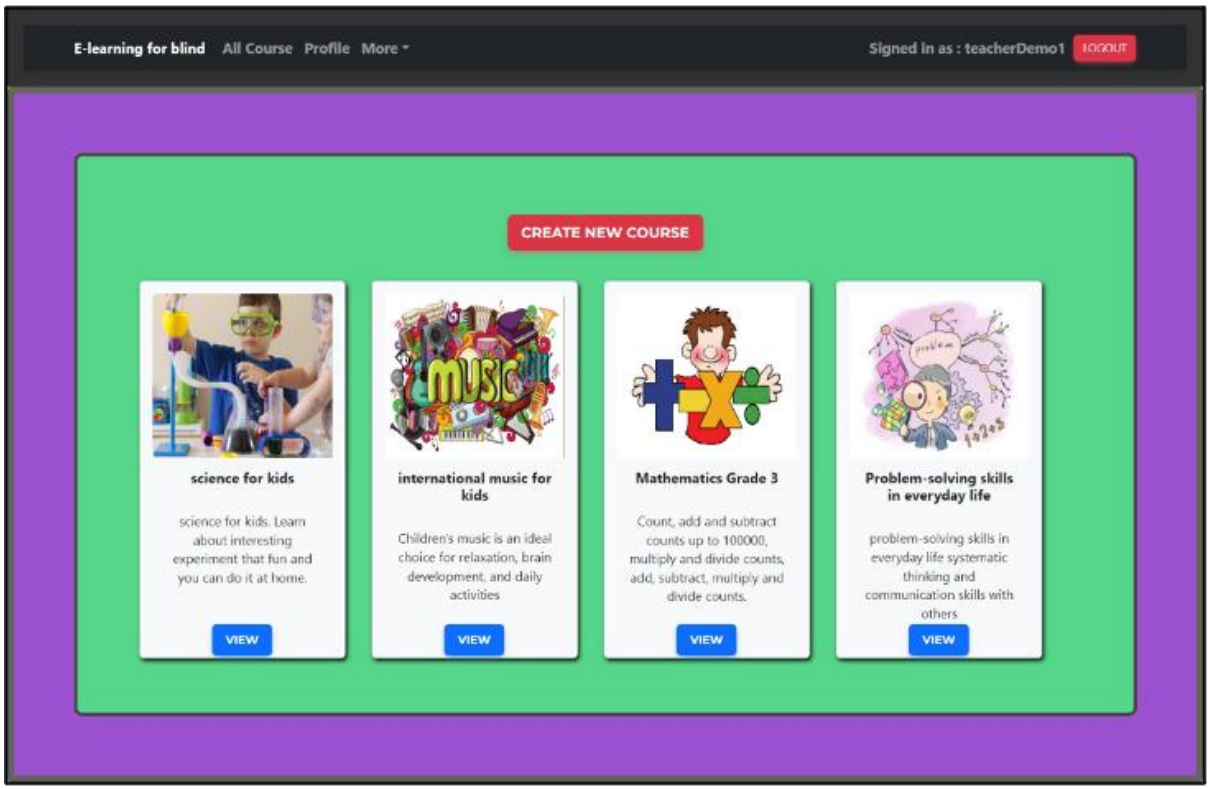

Figure 7 Course Management System

The framework implemented within this system facilitates a dynamic learning environment where instructors possess the capacity to design and deploy engaging educational content. Specifically, the system integrates intuitive Lesson Management tools, enabling educators to seamlessly develop and incorporate lessons into structured course curricula, thereby establishing a coherent learning trajectory. To ensure effective knowledge transfer and assess student comprehension, comprehensive Assessment Tools are provided, allowing for the creation and administration of post-learning quizzes that measure understanding and reinforce key concepts. Furthermore, the platform augments the learning experience through integrated Content Delivery functionalities, supporting the hosting and display of instructional videos, thereby transforming passive learning into an active and immersive process. Student engagement is enhanced through the implementation of User

Profiles, which enable students to participate in assessments, monitor their academic progress, and foster connections with instructors and peers via detailed teacher and student profile (as shown in Figure 8).

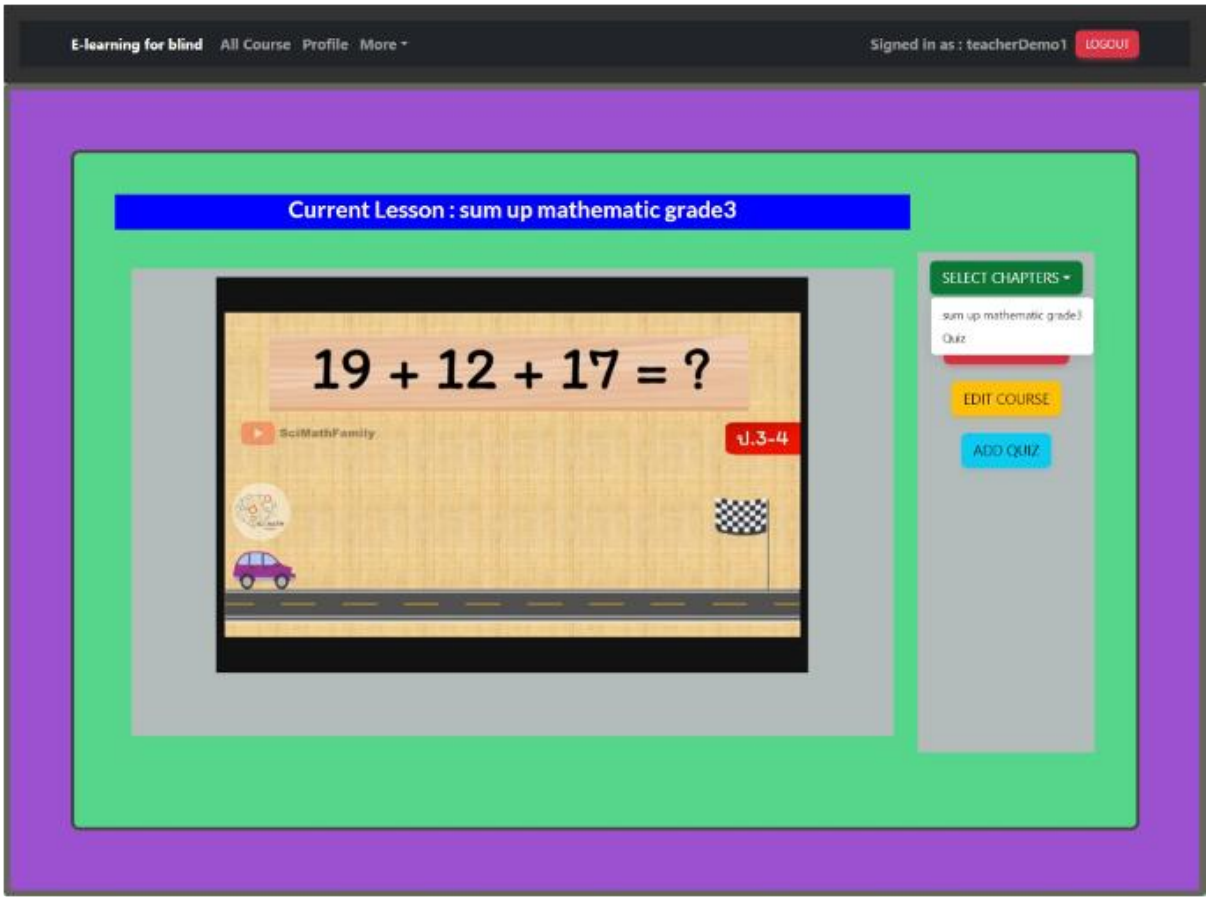

Figure 8 Content was suitable for both general and students requiring assistance.

Audiobook Library Functionality

The Audiobook section (as shown in Figure 9) of the platform provides a comprehensive environment for the management and consumption of auditory content. Specifically, the system facilitates Audiobook Access through an interface that presents a catalogue of available audiobooks and enables direct playback. Further, the platform supports Content Creation by empowering users to upload and generate their own audiobooks, including the ability to upload individual episodes. A feature for Audio Recording is integrated, allowing users to record audio directly within the website. Finally, Content Management functionalities enable users to edit and manage their uploaded audiobook materials.

The platform also incorporates Online Radio Functionality, providing users with access to online radio broadcasts.

A Help Center Resources section is included, serving as a centralized repository of information and support materials designed to assist all users, with a particular emphasis on addressing the needs of visually impaired individuals.

A comparative analysis of Screen Reader and Text-to-Speech (TTS) Interaction with web content was conducted. This analysis focused on the role of semantic HTML and ARIA attributes in optimizing accessibility and ensuring effective interpretation of web content by assistive technologies.

The website's overall Web Accessibility Evaluation was performed utilizing established evaluation tools to verify adherence to accessibility standards. Specifically, the WAVE Web Accessibility Evaluation Tool was employed to assess the website's accessibility, and Equally.ai was also utilized for further evaluation (as shown in Figure 10.).

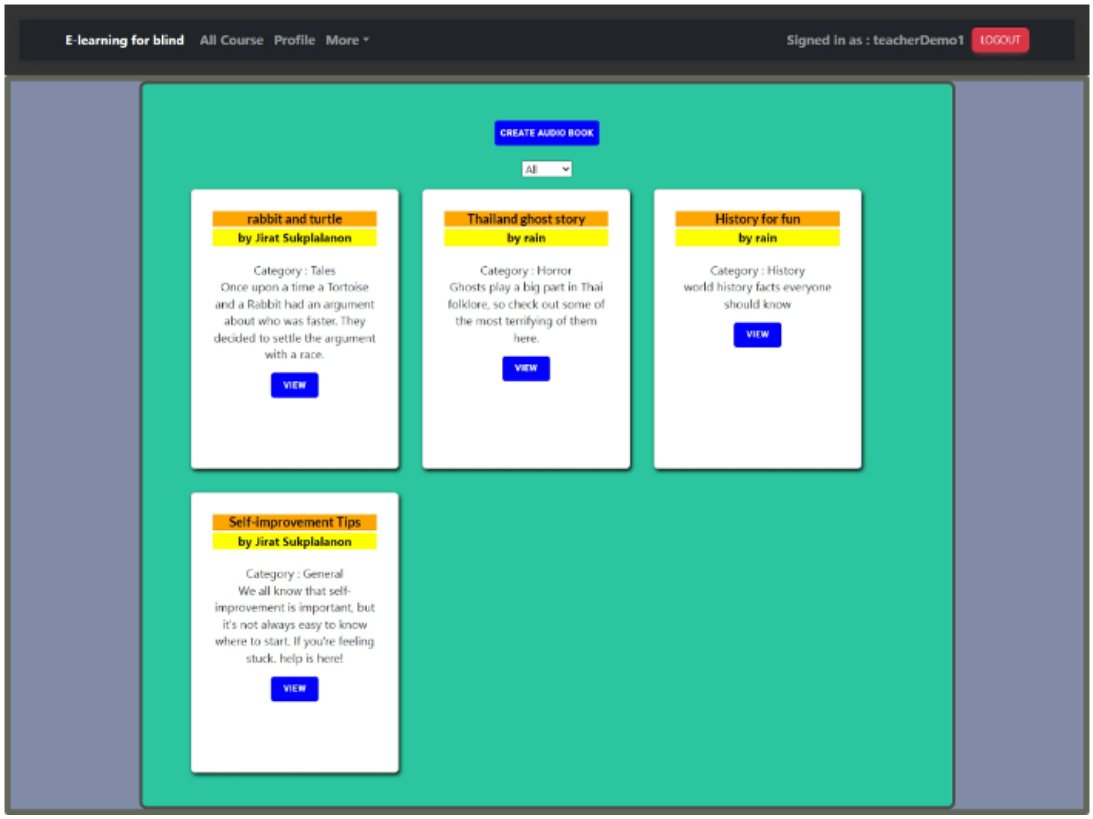

Figure 9 Audio Book section.

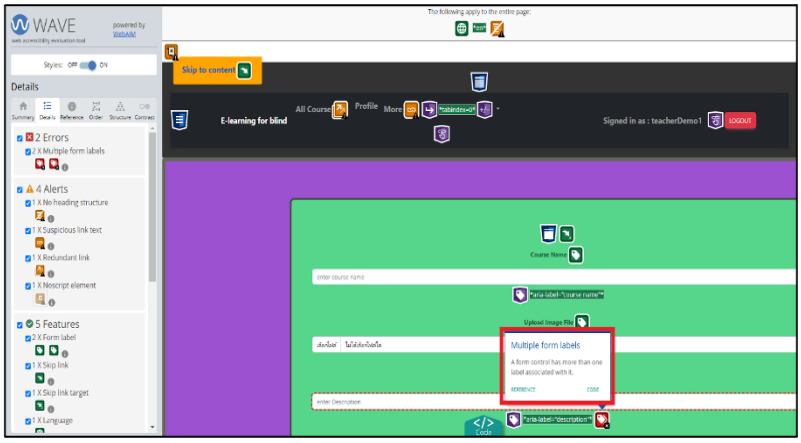

Figure 10 Wave and Equally.ai evaluation tools.

Conclusion

An e-learning website designed to be accessible to visually impaired users was developed, adhering to WCAG 2.0 guidelines. The website provides four core functions: an E-learning system, an audiobook library, an online radio feature, and a help center. The project successfully achieved AAA level compliance with WCAG 2.0 criteria, demonstrating a high level of accessibility.

The project encountered challenges related to ensuring compatibility across diverse screen readers, difficulties in conducting extensive testing with a broad range of visually impaired users, and limitations in the text-to-speech functionality when handling complex content.

The website's features are primarily tailored to support visually impaired users. The E-learning system provides core functionalities but could benefit from further development to include more advanced features. The audiobook and online radio features rely on external sources, which may introduce dependencies related to content availability and quality.

Future development efforts should focus on enhancing compatibility with a wider array of assistive technologies, expanding the E-learning system with features such as collaborative learning tools and personalized learning paths, improving the audiobook and online radio features by integrating with more robust content sources, developing a mobile application to improve accessibility and convenience, and conducting further user testing with a larger and more diverse group of visually impaired individuals to gather feedback and identify areas for further enhancement.

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