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SUSTAINABLE TECHNOLOGY-ENHANCED LEARNING FOR LEARNERS WITH DYSLEXIA

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***Abstract*— The rapid advancement of web technologies has significantly transformed modern education by enabling innovative accessibility solutions for diverse learners. However, most existing assistive tools for dyslexia are either limited to single functionalities or require costly subscriptions, making them inaccessible to a large population. To overcome these limitations, this project presents "DyslexEase", a sustainable, AI-powered web-based platform designed to support individuals with dyslexia through an integrated and user-friendly interface. The proposed system combines multiple assistive features, including dyslexia-friendly text formatting, text-to-speech conversion, text-to-image visualization, and a customizable reading environment. By leveraging technologies such as HTML5, CSS3, JavaScript, and Python Flask, along with browser-based APIs like the Web Speech API and AI-driven image generation, the platform delivers real-time, accessible learning support. Users can input text, upload documents, or use OCR-based inputs to receive optimized outputs that enhance readability and comprehension.**

Unlike existing fragmented solutions, DyslexEase provides a unified platform that reduces cognitive load and improves learning efficiency. The system is designed as a progressive web application, ensuring accessibility across devices, including low-end smartphones. Additionally, it aligns with global sustainability goals such as Quality Education, Reduced Inequalities, and Good Health and Well-being. The proposed solution demonstrates how integrating artificial intelligence with accessible web design can bridge the gap between technology and neurodiversity. By offering a free, scalable, and inclusive learning tool, DyslexEase aims to improve literacy outcomes, support educators, and promote equitable access to education for individuals with dyslexia.

keywords—Dyslexia, Assistive Technology, AI-based Learning, Text-to-Speech, Text-to-Image Visualization, Dyslexia-Friendly Text Formatting, Web Accessibility, Inclusive Education, Neurodiversity, Optical Character Recognition (OCR), Progressive Web Application (PWA), Human-Computer Interaction, Personalized Learning, Educational Technology, WCAG 2.1 Compliance, Sustainable Development Goals (SDG 4, SDG 10, SDG 3)

I. INTRODUCTION

In recent years, the rapid growth of digital technologies has transformed the educational landscape, enabling new methods of teaching and learning. Despite these advancements, a significant gap still exists in providing accessible learning environments for individuals with learning disabilities, particularly dyslexia. Dyslexia is a common neurodevelopmental condition that affects reading, writing, and spelling abilities, making it difficult for learners to process textual information efficiently. Traditional learning systems and digital platforms often fail to address the specific needs of dyslexic learners, resulting in reduced academic performance, low confidence, and limited access to quality education Existing assistive technologies for dyslexia offer partial solutions, such as text-to-speech or basic text formatting. However, these systems are often fragmented, requiring users to switch between multiple applications to access different features. Moreover, many advanced tools are commercial and expensive, making them inaccessible to learners from economically disadvantaged backgrounds. This lack of affordability and integration creates barriers that hinder inclusive education and widen the learning gap.

To address these challenges, this project introduces DyslexEase, a sustainable technology-enhanced learning platform designed specifically for individuals with dyslexia. The system integrates multiple assistive features into a single, user-friendly web application. It includes dyslexia-friendly text formatting, text-to-speech functionality, text-to-image visualization, and customizable reading settings, all aimed at improving readability and

comprehension. By combining these features, the platform reduces cognitive load and provides a seamless learning experience.

The proposed system leverages modern web technologies such as HTML5, CSS3, JavaScript, and Python Flask, along with AI-based tools and browser APIs. It is designed as a progressive web application, ensuring accessibility across various devices, including smartphones and low-bandwidth environments. This makes the solution practical and scalable, especially in developing regions where access to expensive assistive tools is limited.

II. LITERATURE REVIEW

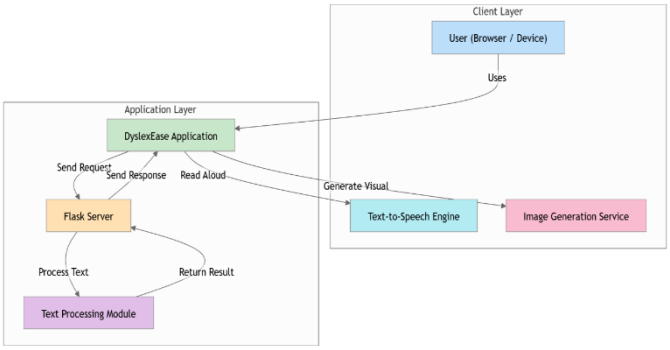
Dyslexia has been extensively studied in the fields of psychology, education, and cognitive neuroscience, with research primarily focusing on understanding its causes and identifying effective intervention strategies. Dyslexia by Margaret J. Snowling provides foundational insights into dyslexia, identifying it as a phonological processing disorder rather than a visual impairment. The study highlights that individuals with dyslexia struggle with sound-letter mapping, which directly impacts reading fluency and comprehension. This work established the basis for many assistive technologies aimed at improving phonological awareness. Further expanding on this, Theories of Developmental Dyslexia: Insights from a Multiple Case Study of Dyslexic Adults by Franck Ramus confirms that phonological deficits are the most consistent characteristic across different types of dyslexia. The research also indicates that while some individuals may exhibit auditory or visual processing difficulties, these are not universal, reinforcing the importance of designing solutions that primarily address phonological challenges.

Accessibility in digital platforms has also been a significant area of research. Benchmarking Web Accessibility Evaluation Tools emphasizes the importance of adhering to accessibility standards such as WCAG guidelines. The study reveals that automated tools alone are insufficient to ensure accessibility, and a user-centered design approach is necessary to effectively support individuals with cognitive disabilities, including dyslexia. Typography and visual presentation play a crucial role in improving reading performance for dyslexic users. The Effect of a Specialized Dyslexia Font, OpenDyslexic, on Reading Rate and Accuracy demonstrates that specialized fonts like OpenDyslexic significantly enhance reading speed and accuracy by reducing letter confusion. The study shows that proper font design can minimize common reading errors, especially in younger learners.

Assistive technologies such as text-to-speech (TTS) have also proven to be highly effective. Computer Reading Machines for Poor Readers highlights that TTS tools improve reading comprehension by allowing users to focus on understanding rather than decoding text. This is particularly beneficial for individuals with severe dyslexia, as it reduces cognitive load and enhances learning outcomes.

III. METHODOLOGY

A. SYSTEM ARCHITECTURE



The methodology of the proposed system, DyslexEase, focuses on designing and developing an integrated, user-friendly web platform that supports dyslexic learners through the application of artificial intelligence and accessibility-driven design principles. The system follows a systematic approach that begins with data input, processing, feature integration, and output generation to ensure an effective learning experience.

Initially, the system accepts input in multiple forms, including manually entered text, uploaded documents such as PDFs, and images processed through Optical Character Recognition (OCR). This input is then preprocessed to remove unnecessary characters, normalize the content, and divide the text into meaningful units such as sentences and words. This preprocessing stage ensures that the data is structured and suitable for further operations.

The core functionality of the system lies in its dyslexia-friendly text formatting mechanism. The input text is transformed into a more readable format by applying techniques such as shorter line segmentation, increased spacing between letters and words, and the use of specialized fonts. These adjustments are based on established research that improves readability and reduces cognitive strain for dyslexic users. The formatted output is presented in a clear and visually comfortable layout.

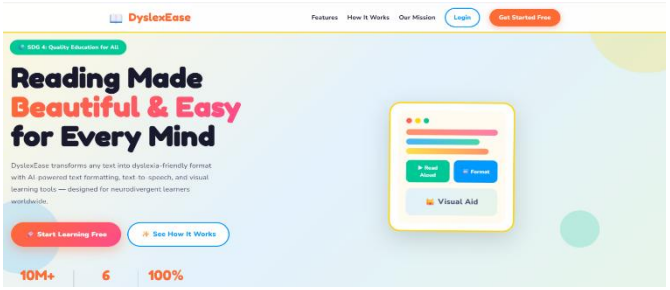
To further enhance understanding, the system integrates a text-to-speech feature that converts written content into audio using browser-based speech synthesis technology. This allows users to listen to the content while simultaneously viewing it, improving comprehension and reducing the dependency on reading alone. Additionally, the system incorporates a text-to-image visualization feature, where textual descriptions are converted into relevant visual representations. This supports visual learning and aligns with cognitive theories that emphasize the effectiveness of combining verbal and visual information.

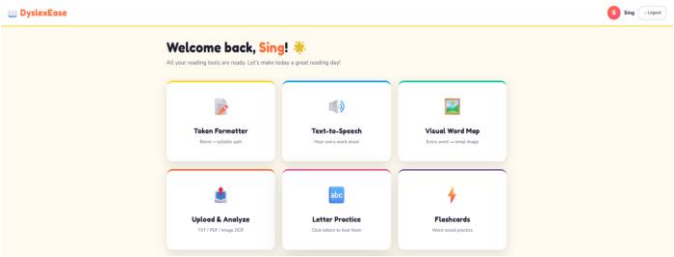
The system also includes a customization mechanism that allows users to adjust display settings such as font size, background color, spacing, and reading speed according to their personal preferences. This personalization ensures that the platform caters to the diverse needs of different users.

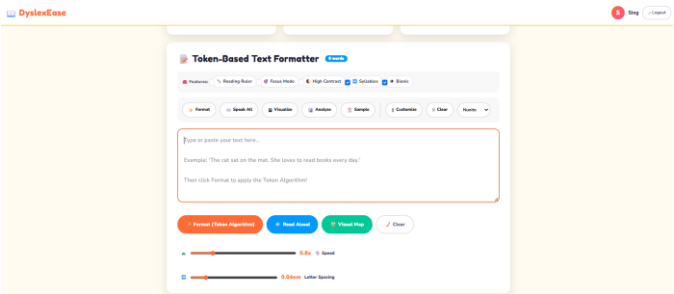
VI. EXPERIMENTAL RESULTS AND ANALYSIS

The experimental evaluation of the proposed system, DyslexEase, was conducted to assess its effectiveness in improving readability, accessibility, and overall user experience for individuals with dyslexia. The system was tested across different scenarios, including text formatting, text-to-speech functionality, text-to-image visualization, and document processing, to validate its performance and usability.

The results demonstrate that the dyslexia-friendly text formatting significantly improves readability by restructuring text into shorter lines, increasing spacing, and applying appropriate fonts. Users were able to read formatted content more comfortably compared to raw text, with reduced visual stress and fewer reading errors. This confirms that formatting techniques play a crucial role in enhancing reading efficiency for dyslexic learners.

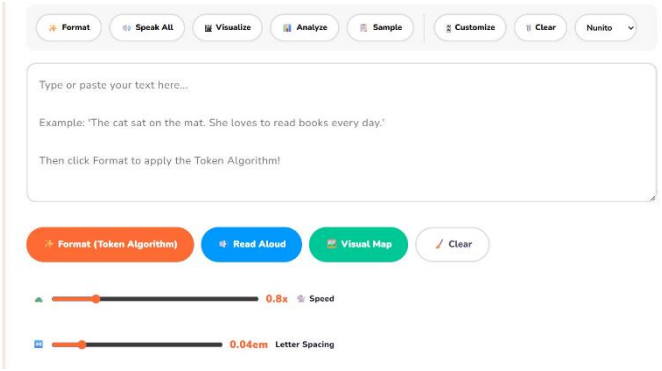


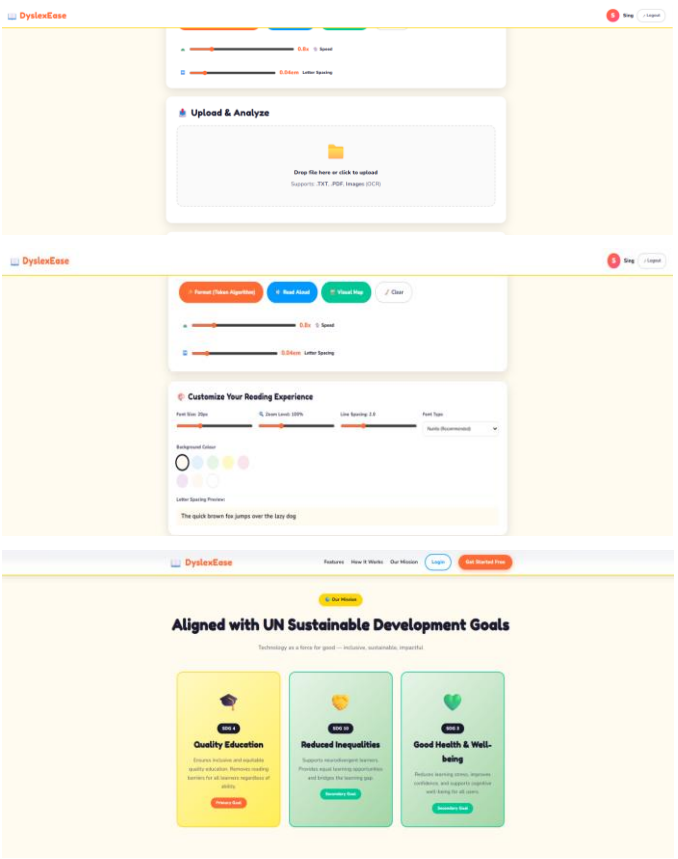




The text-to-speech feature showed consistent performance in converting text into clear and understandable audio output. Users benefited from listening to the content while reading simultaneously, which improved comprehension and reduced the cognitive effort required for decoding words. Minor variations in performance were observed across different web browsers due to differences in speech synthesis support, but overall functionality remained reliable after optimization.

The text-to-image visualization module provided additional support for visual learners by generating relevant images based on textual input. This feature helped users better understand complex or abstract content by associating it with visual representations. The integration of visual learning significantly enhanced user engagement and retention, especially for users who struggle with purely text-based information.





The OCR and file upload functionality successfully extracted text from images and PDF documents, enabling users to process real-world learning materials. Although slight delays were observed when handling large files, the system maintained acceptable performance levels through efficient preprocessing and asynchronous operations.

Customization features played a vital role in improving user satisfaction. Users were able to personalize their reading environment by adjusting font size, spacing, colors, and reading speed. This adaptability ensured that the platform could cater to individual preferences, making it more inclusive and user-centric.

From a performance perspective, the system achieved fast response

times for most operations, with text formatting and speech generation occurring within a few seconds. The modular architecture allowed smooth interaction between components, ensuring system stability even when multiple features were used simultaneously. However, performance limitations were noted when processing large inputs or under heavy usage, indicating scope for further optimization.

V. CONCLUSION

The DyslexEase system successfully demonstrates how modern web technologies and artificial intelligence can be utilized to create an effective, accessible, and inclusive learning platform for individuals with dyslexia. The project addresses critical limitations found in existing assistive tools, such as high cost, lack of integration, and limited accessibility, by providing a unified, free, and user-friendly solution. By integrating key features such as dyslexia-friendly text formatting, text-to-speech conversion, text-to-image visualization, and customizable reading settings, the system significantly improves readability and comprehension. The platform reduces cognitive load and enables users to engage with textual content more efficiently, thereby enhancing their learning experience. The use of a modular architecture ensures that the system is scalable, maintainable, and adaptable for future enhancements.

The implementation of DyslexEase as a progressive web application further strengthens its practicality, allowing it to function seamlessly across different devices and environments, including low-resource settings. This ensures that assistive learning tools are accessible not only to privileged users but also to learners from diverse socio-economic backgrounds. Moreover, the project aligns with global initiatives such as inclusive education and sustainable development by supporting goals related to quality education, reduced inequalities, and improved well-being. It emphasizes the importance of leveraging technology to bridge educational gaps and promote equal opportunities for all learners. In conclusion, DyslexEase stands as a meaningful contribution toward accessible education, combining technical innovation with social impact. The system not only enhances the learning capabilities of dyslexic individuals but also sets a foundation for future advancements in AI-driven assistive technologies.

VI. FUTURE SCOPE

The DyslexEase system, while effective in its current form, offers significant opportunities for further enhancement and expansion to improve functionality, intelligence, and user experience. Future developments can focus on integrating advanced artificial intelligence techniques and expanding accessibility features to make the platform more adaptive and globally applicable. One important area of improvement is the incorporation of deep learning-based reading difficulty prediction. By training machine learning models on large linguistic datasets, the system can provide more accurate and personalized difficulty analysis, enabling adaptive content recommendations based on individual user capabilities.

Another promising enhancement is the implementation of real-time OCR using mobile cameras, allowing users to instantly capture and process text from books, documents, or real-world environments. This would make the system more practical for everyday learning scenarios and increase its usability beyond digital text. The development of personalized learning profiles is also a key future direction. By tracking user behavior, preferences, and progress over time, the system can automatically adjust formatting, reading speed, and assistance levels, creating a fully customized learning experience for each user.

To make learning more engaging, gamified reading modules can be introduced. Interactive exercises, quizzes, and phonological training games would help users improve reading skills in an enjoyable and motivating way, especially for younger learners. Expanding the platform to support multiple languages is another critical enhancement. This would allow DyslexEase to serve a global audience, addressing language-specific dyslexia challenges and promoting inclusive education worldwide.

Additionally, a teacher and parent dashboard can be developed to monitor learner progress, track reading improvements, and provide insights into user performance. This would strengthen the system's role in educational environments. Future versions may also include offline functionality through full Progressive Web App (PWA) capabilities, enabling users to access essential features without an internet connection, which is particularly beneficial in low-connectivity regions. Integration with Learning Management Systems (LMS) such as Google Classroom or Moodle can further enhance usability in academic institutions, allowing seamless sharing of assignments and learning materials. Finally, extending support to wearable devices like smartwatches and audio devices could provide on-the-go assistance, making reading support more flexible and accessible in daily life.

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