Towards a Healthier Utopia: Innovating for Women and Children's Well-Being in Tunisia

"LexiPal"

Words That Find Their Way

Lexi Team

Abstract

Dyslexia is a common learning disorder that affects reading, writing, and spelling, often leading to frustration and reduced academic confidence among children[1]. Although it can be hereditary, with the right strategies and tools, children can overcome these difficulties and focus on their strengths. Unfortunately, many remain unaware of their condition or misunderstand their challenges, which can affect their self-esteem and motivation[1].
This report highlights the importance of dyslexia awareness among children and proposes ways to support those affected. Awareness activities were designed to address two key aspects: helping children with dyslexia manage their struggles, and helping non-dyslexic children understand and support their dyslexic peers.
In addition, the report introduces a Smart Pen as a technical solution to assist children who struggle with reading. Equipped with a miniature camera, optical character recognition (OCR), and text-to-speech (TTS) technology, the pen provides real-time auditory feedback to enhance comprehension and confidence. The device is connected to a dedicated mobile application that offers a child-friendly learning environment, restricts access to other apps during reading sessions, and notifies parents if the child attempts to leave the learning mode. The app also stores a detailed history of scanned words and difficulties encountered, enabling parents to monitor progress over time.
By combining educational awareness with supportive technology and parental monitoring, this project demonstrates a practical and inclusive approach to fostering understanding, empowerment, and equal learning opportunities for all children.

Keywords: dyslexia, reading, smart pen, computer vision, assistive technology.

Introduction

Dyslexia is one of the most prevalent learning difficulties, affecting an estimated 10–15% of children worldwide [2]. Despite its frequency, many cases remain undiagnosed due to limited awareness and understanding, which results in experiencing persistent challenges in reading and writing for affected children who often face frustration and diminished self-esteem[1]. Many continue to believe that they are at fault, rather than recognizing dyslexia as a specific learning difference that can be effectively supported.
To address this issue, a smart pen prototype has been developed to help children with dyslexia in improving their literacy skills. This device integrates assistive technology to enhance writing accuracy, support word recognition, and foster independent learning. By providing accessible, real-time guidance, the solution aims to empower dyslexic learners and enhance confidence in their educational journey.

1. Related Work

The available assistive tools for dyslexic learners, such as the C-Pen Reader and OrCam Read, combine optical character recognition (OCR) and text-to-speech (TTS) technologies to provide advanced reading accessibility. Although these devices deliver immediate reading assistance, they often treat the child as a passive user rather than an active learner. Since the pen performs the reading task for the child, motivation to practise independent reading and spelling can decline; in addition, many current tools offer limited options for parents to track overall progress or engagement.

Our project introduces a Smart Pen prototype designed to overcome these limitations by encouraging active participation and progressive improvement. The pen is connected to a mobile application that simplifies usage and serves as a dedicated learning environment. Parents can supervise their child's engagement through instant notifications or email alerts when a child attempts to exit the reading session or interrupt their activity. The pen supports step-by-step learning by placing the child at the center of the process: when the child encounters a difficult word and needs assistance, they deliberately press the pen to scan it, triggering contextual help instead of automatic reading. This approach promotes effort and autonomy while ensuring support is available when needed. A complete history of scanned words, encountered difficulties, and progress over time is stored within the application, enabling parents to easily monitor their child's learning development.

By combining real book interaction with guided assistance, parental control features, and continuous progress tracking, our Smart Pen shifts reading from a passive activity to an active, structured learning experience.

2. Methodology/ Materials and Methods

This section describes the methodology adopted in developing the system, including the hardware components, software tools, and implementation steps.

2.1. Hardware Components

The hardware architecture of LexiPal is designed around a compact, pen-shaped form factor (40mm diameter × 140mm length) that integrates all necessary components for portable text scanning and processing. Figure 1 illustrates the main components, while Table 1 summarizes their specifications.

Category	**Details**
Main Processing Unit	ESP32-CAM module with OV2640 camera for image capture and Wi-Fi connectivity.
Power Management	• LiPo Battery 3.7V – 2000mAh • MT3608 boost converter (3.7V → 5V)
Audio and Connectivity	Wi-Fi transmission to a mobile app providing Text-to-Speech (TTS) synthesis.

Category	Details
Programming Interface	ESP32-CAM-MB converter for debugging and firmware updates.
Control Interface	Simple touch button for text capture.

Table 1: Hardware components and system specifications

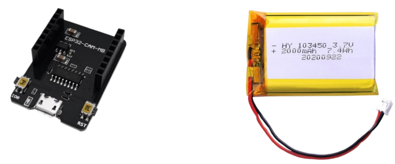

Figure 1: Hardware components of the LexiPal smart pen

2.2. Software and AI Pipeline

The system's functionality is implemented through a sequential software pipeline:

Stage	Description
Video Stream Capture (ESP32-CAM)	ESP32-CAM module captures live video frames via MJPEG stream over WiFi. Frames are transmitted to the Python OCR server through HTTP REST API at configurable frame rates (default: 10 FPS).
Image Preprocessing	Captured frames undergo preprocessing using OpenCV: grayscale conversion (cvtColor), adaptive thresholding (OTSU method), and median blur noise removal (kernel size: 5) to optimize OCR accuracy.
Language Detection	The system performs automatic language detection using the langdetect library on preliminary OCR text. Supports Arabic, English, and French with fallback to default language if detection fails or text is insufficient.
Optical Character Recognition (OCR)	Tesseract OCR engine processes preprocessed images with detected language parameters. The system extracts both full text and character-level bounding boxes for precise text localization and analysis.
Spell Correction	Extracted text undergoes built-in spell correction using custom dictionaries for common OCR errors and educational/scientific terminology. Corrections are logged with original and corrected word pairs.

Stage	Description
Text Simplification	For dyslexic users, complex text is automatically simplified using built-in dictionaries that replace academic/complex terms with simpler alternatives (e.g., "photosynthesis" → "how plants make food").
Keyword Extraction & Definitions	The system automatically extracts keywords (words longer than 5 characters) and generates simple definitions from built-in educational dictionaries covering scientific, civic, and academic terminology.
Translation (Hybrid)	Translation is handled via hybrid approach: Google ML Kit for on-device translation (Arabic, French,english) with pre-downloaded models, and online dictionary API fallback for detailed word definitions when network is available.
Mobile App Interface (Flutter)	Flutter app receives OCR results via HTTP, displays original and simplified text, highlights keywords with definitions, and provides accessibility features. Supports both ESP32-CAM live streaming and Python OCR server integration over WiFi.

Table 2: Sequential software pipeline of the system

3. Results and Discussion

A partial functional prototype of the LexiPal system has been successfully developed, comprising two major achievements: the mechanical design of the pen and the development of a user interface.

3.1. 3D Pen Design and Modeling

The pen's design was fully modeled using SolidWorks, resulting in a detailed 3D model that meets the target dimensions of 140 mm in length and 35 mm in diameter. This modeling validated the mechanical integration of all identified hardware components: The ESP32-CAM module is housed in the pen's tip, optimally positioning the camera for text capture. The 3.7V 2000mAh LiPo battery, connected via a JST PH 2.0 mm connector, and the power management boards (MT3608 boost converter) are integrated into the main body , ensuring sufficient autonomy and safe charging via the USB-C port. Ergonomics were prioritized, with a shape facilitating comfortable grip and correct pen orientation during scanning. This 3D model will serve as a direct basis for manufacturing a physical prototype via 3D printing, thereby reducing risks of mechanical incompatibilities.

Figure 2: 3D model of the scanning pen

3.2. User Interface Development

The final mobile frontend application was developed to provide a complete interface for interaction, learning, and parental supervision. Its design emphasizes simplicity, accessibility, and adaptability to different user needs. The home screen displays scanned words along with contextual assistance, highlighting difficult words and providing step-by-step guidance rather than automatic reading. The Profile screen allows users to manage personal information, language preferences, and learning settings. Audio settings offer control over volume, reading speed, and voice type, supporting personalized reading experiences. The History section organizes all scanned words, tracked difficulties, and progress over time, enabling parents to monitor engagement and learning development through notifications or email alerts. Additionally, the Translation and Definitions screen delivers instant translations and simplified explanations for complex terms. The overall interface uses clear layouts, contrasting colors, and readable typography to enhance accessibility while encouraging active participation and autonomous learning.

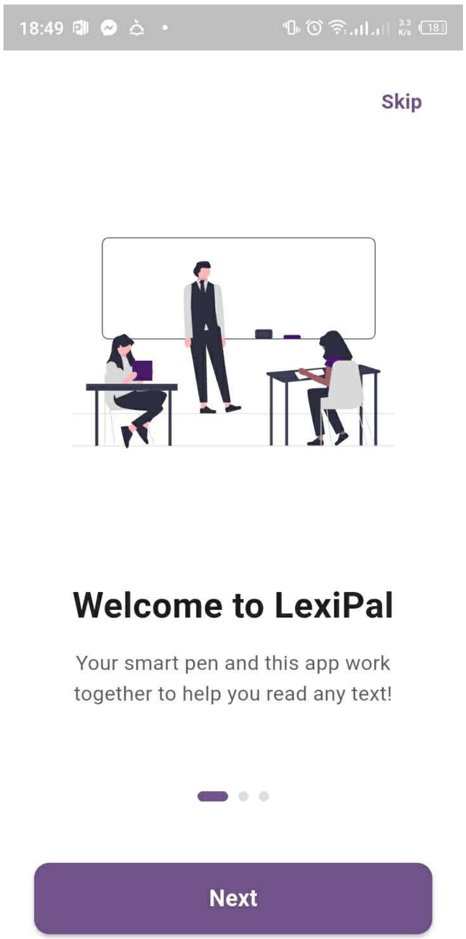

Figure 3: App interface

4. Discussion and Validation of Design Choices

The completed Dyslexia Smart Pen confirms the validity of the key design principles.
Ergonomics and Feasibility: The final hardware prototype successfully integrates complex electronics into a compact, lightweight, and ergonomic pen suitable for children.
User-Centered Interface: The mobile application allows customization of audio settings and reading assistance features, effectively addressing the needs of dyslexic users.
Architecture and Integration: Delegating heavy processing tasks (OCR, TTS, translation) to the smartphone ensured a low-power, affordable pen while maintaining stable and responsive Wi-Fi communication. Full system integration and user testing validated performance, usability, and ergonomics.
Overall, the final device demonstrates that the initial design choices were appropriate and effective, producing a reliable and user-friendly tool for supporting dyslexic children.

Conclusion and Future Work

Future work will focus on further improving both the hardware and software aspects of the system. On the application side, we plan to enhance the learning experience by introducing an adaptive assistance mechanism: when a word is scanned, the corresponding text will initially appear in an encoded form within the application, encouraging the child to attempt decoding it independently. If the child is unable to identify the correct answer after three attempts, the text will be automatically decoded, and the correct answer will be clearly displayed and pronounced aloud to provide guided support.

At the prototype level, we also aim to improve the quality and reliability of the hardware components, ensuring better performance, durability, and comfort of use. These enhancements will contribute to making the Dyslexia Smart Pen a more effective, accessible, and impactful educational assistant for dyslexic learners.

Moving forward, our next objective is to present the Dyslexia Smart Pen solution to government institutions, private schools, and child-support associations. The goal is to introduce this tool to dyslexic children and integrate it into educational environments where it can provide meaningful support. By collaborating with these stakeholders, we aim to help children with dyslexia access better learning conditions and build a stronger path toward their academic and professional development.

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