KHAZANAH MULTIDISIPLIN
VOL 6 NO 2 2025
https://journal.uinsgd.ac.id/index.php/kl

Development of Arabicara: An Arabic Language Learning Application for the Visually Impaired

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Received: September 9, 2025, Revised: October 10, 2025, Approved: October 25, 2025

ABSTRACT

Visually impaired individuals often face limitations in accessing Arabic language learning because conventional media, such as Braille books, do not fully support independent learning. This study aims to develop Arabicara, a cloud-based mobile application featuring text-to-speech, voice navigation, OCR, a dictionary, and interactive exercises. The method used is Research and Development (R&D) with an Agile–Scrum approach, including direct trials with 21 visually impaired respondents. The test results show a significant increase in the average posttest score (80.2) compared to the pretest (47.5). Most respondents stated that the application was easy to access, interactive, and helpful for self-learning, despite issues with the need for a stable internet connection. Thus, Arabicara is considered capable of enhancing the inclusivity of Arabic language learning for the visually impaired.

Keywords: accessibility, Arabic, mobile, visually impaired

ABSTRAK

Penyandang tunanetra sering mengalami keterbatasan dalam mengakses pembelajaran Bahasa Arab karena media konvensional seperti buku Braille belum sepenuhnya mendukung kemandirian belajar. Penelitian ini bertujuan mengembangkan Arabicara, aplikasi mobile berbasis cloud dengan fitur text-to-speech, navigasi suara, OCR, kamus, dan latihan interaktif. Metode yang digunakan adalah Research and Development (R&D) dengan pendekatan Agile–Scrum serta uji coba langsung pada 21 responden tunanetra. Hasil pengujian menunjukkan rata-rata nilai posttest (80,2) meningkat signifikan dibandingkan pretest (47,5). Sebagian besar responden menyatakan aplikasi

mudah diakses, interaktif, dan membantu belajar mandiri, meskipun masih terkendala pada kebutuhan koneksi internet stabil. Dengan demikian, Arabicara dinilai mampu meningkatkan inklusivitas pembelajaran Bahasa Arab bagi penyandang tunanetra. **Kata kunci**: aksesibilitas, aplikasi mobile, bahasa Arab, tunanetra.

I. INTRODUCTION

1.1 Background

The conventional methods of learning Arabic rely heavily on visual aids, including printed texts, diagrams, and graphic user interfaces. This visual dependency poses a significant barrier for individuals with visual impairments (VI), profoundly limiting their ability to access educational materials independently and efficiently. The necessity for manual conversion or continuous third-party assistance hinders the development of autonomous learning skills and reduces educational equity.

The magnitude of this challenge underscores the critical need for inclusive technological solutions. Data from the World Health Organization (WHO) highlights that at least 2.2 billion people worldwide live with a near or distance vision impairment, with nearly half of these cases being preventable or unaddressed (World Health Organization, 2023). Specifically addressing the most severe cases, the International Agency for the Prevention of Blindness (IAPB) reports that an estimated 43 million people are living with blindness (IAPB, 2021). This global prevalence of VI emphasizes the urgency to bridge the accessibility gap within language education (Al-Husban, 2022).

This research aims to address this critical void by developing a specialized technological solution. The problem can be formulated through three core research questions guiding this study (Pradana & Pratiwi, 2022), Firstly, How can the limitations of visually impaired individuals in accessing Arabic language learning materials independently be overcome?.

What are the most relevant and effective technological features to enhance accessibility (J. Zhang & Chen, 2022) and interaction in an Arabic language learning application? And finally, the implementation challenge “How can a mobile Arabic language learning application that is visually-impaired-friendly, interactive, and fosters independent learning be successfully designed and developed?”

To fulfill this aim, the study sets out with integrated objectives. We must first analyze the specific needs and interaction methods of visually impaired individuals when engaging with non-visual Arabic learning content. Following this analysis, the study aims to determine the appropriate technological features such as comprehensive *screen reader* compatibility (Nakamura et al., 2022) haptic feedback mechanisms, and intuitive voice-activated controls required to fully support an accessible and interactive learning experience (A. Rahman et al., 2023).

II. RESEARCH METHODOLOGY

2.1.1 Type and Research Approach

This research adopts a *Research and Development (R&D)* method to design, develop, and evaluate an accessible Arabic language learning application for visually impaired users. The *R&D* approach was selected because it emphasizes the creation of practical and user-oriented solutions through iterative design, prototyping, and testing. The goal of this method is to bridge the gap between theoretical design and its real-world implementation by ensuring that the resulting product is functional, efficient, and aligned with user needs. (Gomez et al., 2023)

To guide the development process, the study employs the *Agile Software Development* methodology, specifically the *Scrum* framework, which emphasizes adaptability, collaboration, and continuous improvement (Schwaber & Sutherland, 2020). Scrum divides the development cycle into short, time-boxed iterations known as *sprints*, typically lasting one to four weeks. Each sprint begins with *Sprint Planning* to determine the backlog tasks, followed by *Daily Scrum* meetings to monitor progress, and concludes with *Sprint Review* and *Sprint Retrospective* sessions to evaluate outcomes and identify improvements for the next iteration.

This framework was chosen because it aligns with the dynamic nature of software development for assistive technologies, where user feedback plays a critical role in improving usability and accessibility. Throughout the development, user input was continuously integrated into the refinement process. Testing and feedback from visually impaired

participants were collected after each sprint cycle, ensuring that the resulting prototype evolved based on real user experiences rather than assumptions.

2.2 User Requirements

The user requirements were identified through direct interviews and field observations with visually impaired individuals, supported by a review of relevant literature. The findings emphasize that accessibility, intuitive navigation, and auditory interaction are the primary needs for visually impaired users in a digital learning environment.

First, users require audio-based learning materials accompanied by text transcripts. This multimodal format allows the material to be accessed independently or collaboratively with teachers or family members, enabling flexible learning experiences. Most interview participants stated that they better understood the content when it was presented through synchronized audio and text, confirming that auditory delivery plays a central role in their learning process (Ali et al., 2020).

Second, a consistent voice-based navigation system is essential. Both the interviews and previous studies indicate that inconsistent audio feedback or unclear button prompts can disorient users and hinder navigation (O'Connor & Hosseini, 2021). Therefore, the system must provide clear and repeatable auditory cues across all menus and interactive elements to ensure ease of use and memorability (Ali et al., 2020).

Third, users expressed a need for interactive audio-based exercises that offer immediate feedback. These exercises allow learners to independently assess their comprehension through voice responses indicating correct or incorrect answers (Toh et al., 2021). Participants highlighted that such real-time auditory feedback improves engagement and reinforces understanding without requiring visual input (Ali et al., 2020).

Fourth, the application should support Text-to-Speech (TTS) customization, including adjustable speech speed and intonation. This flexibility enhances comfort and personalization, as users' auditory

preferences vary according to their learning pace and cognitive rhythm [12]. Several respondents mentioned that slower voice delivery improved comprehension, while others preferred faster playback for efficiency (Essien et al., 2021).

2. 3 Testing Method

The testing process in this study consisted of two stages: internal testing using the *Black Box Testing* method and external evaluation through a *User Acceptance Test (UAT)* involving visually impaired participants. Both testing stages were integrated into the Agile *Scrum* framework, where feedback collected from each iteration was used to refine and improve the system's functionality and accessibility.

The *Black Box Testing* method was employed to verify whether the system's functions operated as intended based on specific inputs and expected outputs. This approach was selected because it focuses on validating the external behavior of the system without examining the internal code structure. Core features such as login, Text-to-Speech (TTS), Optical Character Recognition (OCR), voice navigation, and interactive quizzes were tested for reliability and consistency. The results confirmed that each function performed correctly under most usage scenarios, with stable response times and accurate output generation.

The second stage involved a *User Acceptance Test (UAT)* conducted with visually impaired users to evaluate the application's usability, accessibility, and overall user satisfaction. The test was carried out through direct interaction sessions in which participants were introduced to the application and asked to perform a set of tasks independently. Observations and interviews were conducted to collect both quantitative and qualitative feedback.

The results of the UAT showed a high level of satisfaction and accessibility among participants. Most users rated the application as easy to navigate and found the auditory feedback features—especially TTS, OCR, and interactive exercises—highly useful in supporting independent learning. Some users provided constructive input regarding the clarity of

audio feedback and the need for simpler navigation paths. This feedback was documented and analyzed to guide improvements in subsequent sprint cycles. RESULTS AND DISCUSSION

3.1 Result

3.1.1 System Design

The system design of the Arabicara application was developed to ensure accessibility, modularity, and scalability while supporting interactive Arabic language learning for visually impaired users. The architecture follows a service-oriented and layered structure consisting of a frontend interface, a backend service layer, and a cloud-based data management system. This architecture ensures clear separation of concerns, making the system easier to maintain and expand.

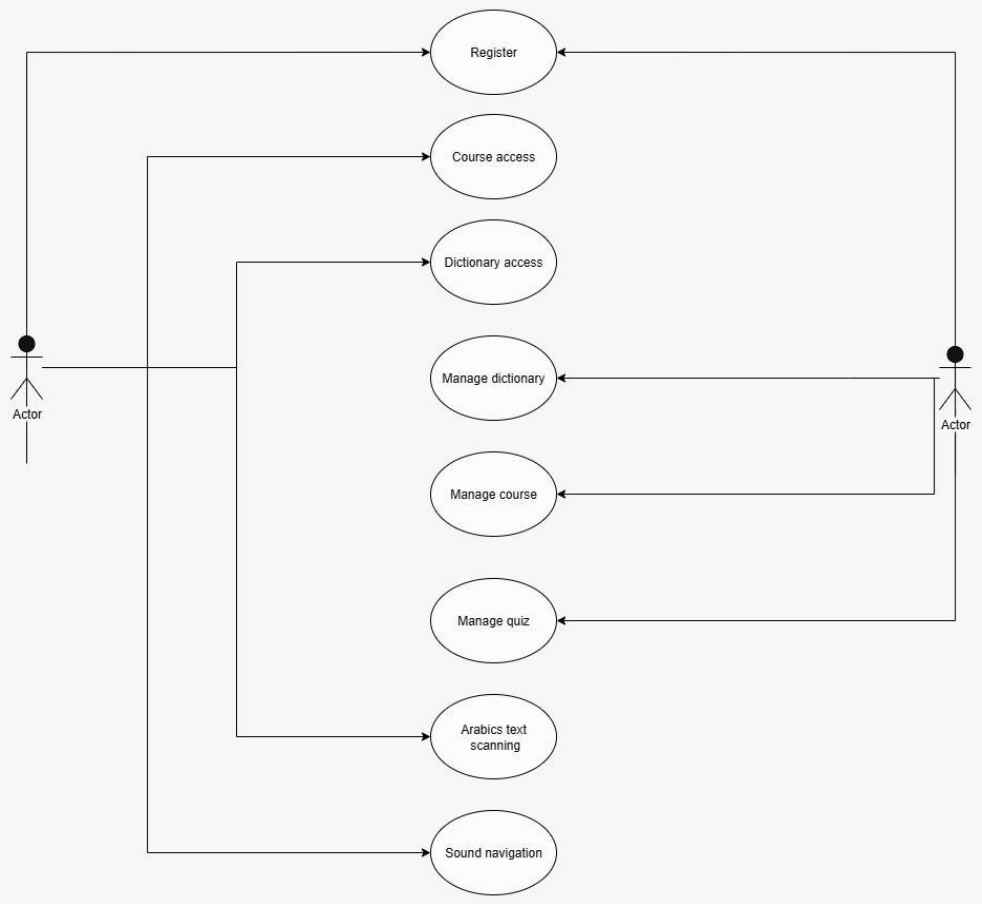

Figure 1. ERD

At the client layer, the system includes two main applications, a

Flutter-based mobile app for users and a React-based dashboard for administrators. The mobile application provides access to learning materials, exercises, and accessibility features such as Text-to-Speech (TTS), Optical Character Recognition (OCR), and voice navigation (Flutter, 2025) The interface is designed to be compatible with assistive tools such as TalkBack and VoiceOver, ensuring that visually impaired users can operate it smoothly. The administrator dashboard allows for CRUD (Create, Read, Update, Delete) management of materials, exercises, and vocabulary, ensuring continuous content updates.

At the backend layer, the application uses a Node.js-based API integrated with Supabase as a Backend-as-a-Service. Supabase manages user authentication through Supabase Auth, data storage in PostgreSQL, and applies Row Level Security (RLS) for controlled data access (Ganesan et al., 2022). The custom Node.js API handles more complex processes, such as authentication token validation, communication with third-party APIs, and execution of core logic for TTS, OCR, and voice-based features.

The data management layer employs a PostgreSQL database through Supabase to store user data, learning progress, and educational content. Media assets, including generated audio, are managed via Cloudinary and Google Cloud Storage for stable retrieval. External APIs—Google TTS, Google STT, and OpenAI GPT-4o mini—support advanced functionality such as voice generation, speech recognition, and OCR-based text extraction from Arabic materials. The system database structure ensures logical relationships between entities users → levels → lessons → exercises → progress tracking, with integrated vocabulary and audio data to support contextual learning (Mohan et al., 2024).

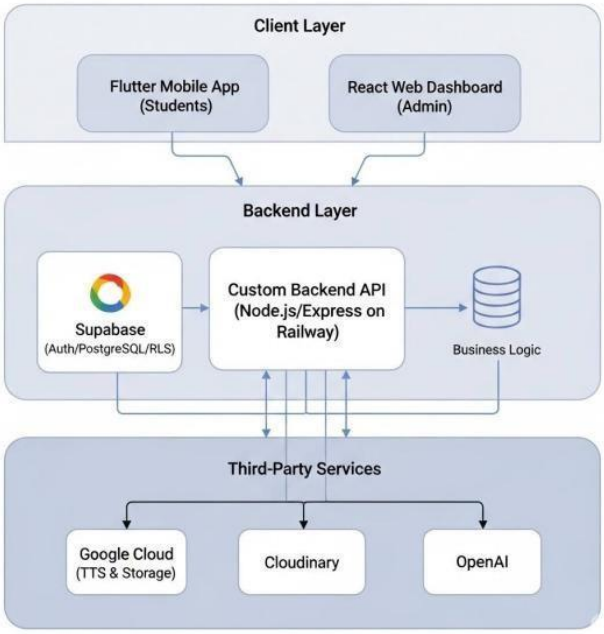

Figure 2. Database Architecture

3.1.2 Design

This section presents the interface design for the Arabic language learning application for the visually impaired. The design focuses on simple navigation, compatibility with screen readers, and audio-based content presentation.

Home Screen

The application's main display features a simple navigation menu with options for the main features are OCR, Materials, Dictionary, and Exercises. Each button is large, has high contrast, and can be read by a screen reader.

Figure 3. Home screen

OCR

The Optical Character Recognition (OCR) feature allows users to scan Arabic text from images or physical documents. After scanning, the resulting text will be automatically read aloud by the TTS (Text-to-Speech) system.

Figure 4. OCR screen

Lessons and Exercises

The lessons section displays Arabic language learning content based on the selected level and lesson. Each lessons consists of a main audio track and a text transcript. Navigation between lessons is linear, and after each lesson, there is an exercise in the form of audio-based questions, such as

multiple-choice or listening and guessing the meaning. Answers are selected using voice commands.

Figure 5. Lessons and exercises screen

Dictionary

The dictionary serves as a quick reference for users to find the meaning of Arabic words. Words can be entered by typing or through voice input. The search results are immediately read aloud by the screen reader.

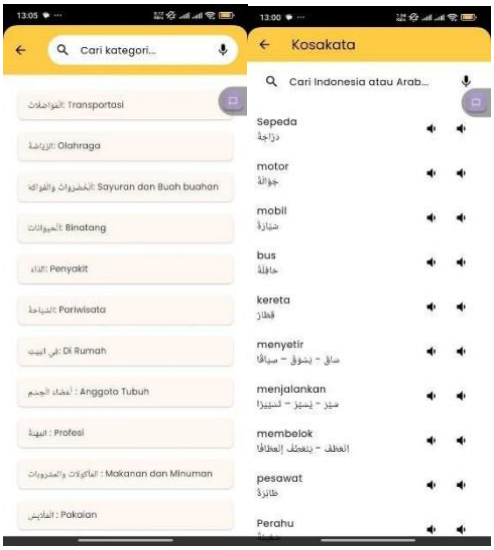

Figure 6. Dictionary screen

Voice Navigation

The voice navigation feature allows users to operate the application without always having to touch the screen. Commands like "Open Materials," "Search in Dictionary," or "Start Exercises" can be used to move between menus.

3.1.3 System Implementation

The development of the Arabicara application was carried out using

a cloud-based mobile application approach, allowing users to access materials flexibly across various devices. The system architecture was designed by separating the mobile app frontend and the cloud service backend. The mobile application handles the user interface and interactions, while the cloud is responsible for storing learning materials, progress, and user data.

The main features successfully implemented include:

1. Text-to-Speech (TTS) Every Arabic text and its translation is equipped with an automatic talkback label to help the visually impaired understand the material.
2. Optical Character Recognition (OCR) Used to recognize Arabic text from images or documents, allowing additional material to be obtained from external sources.
3. Voice-based navigation All menus and buttons in the application are equipped with audio cues, making it easier for visually impaired users to navigate without having to search for the desired feature.
4. Interactive exercises Each lesson includes audio-based practice questions, ranging from multiple-choice to questions about material, vocabulary introduction, and basic Arabic.
5. Cloud database integration All learning progress data (levels, lessons, exercises) is centrally stored using Supabase, which is consistent with the Entity-Relationship Diagram (ERD).

The application interface was also designed to be visually-impaired-friendly with audio-based navigation, a consistent focus order, and minimal use of complex visual elements. With this approach, the application is not only accessible to sighted users but also provides an equivalent learning experience for the visually impaired.

3.1.4 Application Trial Results

The application underwent two stages of evaluation internal testing using the Black Box Testing method and external testing through a User Acceptance Test (UAT) involving visually impaired participants. In the Black Box Testing stage, functional verification was performed to ensure

that each key feature of the system operated according to its design specifications. The main features—login, Text-to-Speech (TTS), Optical Character Recognition (OCR), and voice navigation—consistently produced outputs that matched their respective inputs under various usage conditions. The system was observed to operate stably, with average response times remaining under 1.2 seconds for most operations. The TTS module demonstrated clear and consistent audio output in over 95% of test scenarios, while the OCR function achieved an average recognition accuracy of approximately 88% when processing Arabic text. These results indicate that the system functions reliably within normal operating parameters and can maintain performance even during cloud-based data exchanges.

Following the internal validation, a User Acceptance Test was conducted with 21 visually impaired participants to evaluate accessibility, usability, and satisfaction. The results indicated a generally high level of acceptance and usability. Fourteen participants stated that the application was easy to access via a smartphone, six rated it as very easy, while only two found it difficult and one rated it as average. Integration with screen reader tools (TalkBack and VoiceOver) was also positively received, with 15 participants considering it very helpful and six stating it worked well.

Audio clarity was identified as a notable strength, as 13 participants rated it clear and nine rated it very clear. Navigation was also well-received—16 users rated it as easy to understand, six as very easy, and only one considered it confusing. When asked about the most useful features, six participants highlighted audio-based interactive exercises, four mentioned voice navigation, and two selected TTS, while the remaining respondents valued the combined use of TTS, OCR, and voice-based learning tools. These findings confirm that multimodal accessibility features (audio combined with text) enhance flexibility and inclusivity for diverse learning preferences.

Regarding comfort and engagement, 15 respondents reported feeling comfortable using the application, seven found it very comfortable, and one rated it as average. Additionally, 22 participants indicated that the application significantly improved their learning motivation, either

“helped” or “very helped.” System performance was also positively rated, with 13 participants rating it as good, six as quite good, and four as very good.

Nonetheless, several issues were identified during the testing phase. Thirteen participants reported no problems, but a few mentioned intermittent screen reader inaccessibility (3 participants), unstable internet connections (2 participants), and minor navigation inconsistencies (1–2 participants).

3.1.5 Deployment

The application was successfully deployed by releasing it to the Google Play Store through the Google Play Console. The application was built in Android App Bundle (AAB) format, which was signed using a keystore. Before uploading, metadata such as the application name, description, icon, screenshots, category, and access permission details were completed to comply with Play Store publication standards.

After the upload process, the application went through a verification stage by Google's system. This process included security checks, device compatibility, and compliance with content policies. Despite some adjustments to the file size and permission settings, the application was ultimately approved and received a "published" status. Since then, the application has been available on the Play Store for direct user download.

With the successful deployment, the application is officially released and ready for public use. This stage marks an important milestone, as the system is not only functional in the development environment but has also been made publicly available. This success also opens up opportunities for ongoing maintenance and future version updates based on user needs.

3.2 Discussion

3.2.1 Alignment with User Needs

The findings of this study resonate closely with existing research in assistive and accessible learning technologies, particularly for visually impaired learners (Oliveira et al., 2022). Like many prior studies, this work confirms that traditional modalities—Braille books or teacher-led, text-based instruction—often impede flexibility and independent learning, a limitation similarly noted by (S. Rahman et al., 2023), who developed an interactive web-based Text-to-Speech system for visually impaired users that highlighted usability improvements when learners could access audio with minimal reliance on visual interfaces. Moreover, research such as *Deep Learning Reader for Visually Impaired* (Patel et al., 2022) demonstrates that combining OCR and TTS in reading systems yields higher comprehension and speed for visually impaired individuals when compared to text-only or Braille-only approaches (Hassan et al., 2023).

In this study, user pre-/post-test measurements showed a marked jump in comprehension from an average of ~47.5 to ~80.2, indicating that audio delivery combined with voice navigation and structured content can overcome several of the barriers identified in earlier literature. For instance, the study “Voice-assisted online exam management and usability analysis with visually impaired students” (Kumar et al., 2023) similarly found that features like audio support and screen reading markedly improved users’ ability to complete assessments independently.

Unlike some assistive applications described in prior research that focus solely on reading or navigation in isolation, Arabicara integrates multiple modalities—audio lessons, OCR, quizzes, voice navigation—thus aligning more fully with the multifaceted needs reported by participants. consistent with prior findings, challenges remain audio clarity under varied environmental conditions and dependency on internet connectivity are echoed in studies such as “Voice Navigation System for Visually Impaired” (L. Zhang et al., 2024), which found that environmental noise and network instability degrade user experience significantly.

3.2.2 Feature and Accessibility Analysis

The evaluation results after the trial showed that the application was deemed quite accessible by most respondents. 14 out of 21 respondents stated that the application was easy to access via a smartphone, with 6 even rating it as very easy, although there were still 2 respondents who found it very difficult and 1 who rated it as average. In terms of screen reader (TalkBack/VoiceOver) usage, the application was rated as very helpful by 15 respondents, while 6 respondents said it worked well, and only 2 felt it was only somewhat helpful. This indicates that the integration with assistive technology is quite effective.

Audio quality was also a strong point, with 13 respondents rating the application's voice as clear and 9 as very clear, although 1 respondent rated it as average. The application's navigation was also considered user-friendly, with 16 respondents rating it as easy to understand, 6 as very easy, and only 1 feeling that the navigation was still confusing.

Regarding features, most participants mentioned that the audio-based interactive exercises and voice navigation were the most helpful features. Specifically, 6 respondents chose audio-based interactive exercises, 4 mentioned voice navigation, 2 chose Text-to-Speech (TTS), and several others (around 9 people) combined TTS, OCR, audio exercises, and voice navigation. This confirms that the multimodal features (audio + text) provide flexibility according to individual needs.

In terms of comfort, 15 respondents felt comfortable learning with the application compared to previous methods, 7 stated they were very comfortable, and only 1 rated it as average. Furthermore, learning motivation also increased, with 11 respondents feeling very helped and 11 others helped, and only 1 respondent feeling it was average. The application's performance was also quite stable 13 respondents rated it as good, 6 as quite good, and 4 as very good.

Despite this, there were still some issues. 13 respondents reported no issues, but 3 complained that the screen reader was not always audible, faced unstable internet connection problems, and a small number (1–2 respondents) complained about confusing navigation or inconsistent audio.

Overall, the satisfaction level with the application is very high. This is evident from the 11 respondents who were satisfied and 11 who were very satisfied, with only 1 respondent rating it as average. These findings show that audio-based features, voice navigation, and integration with screen readers are the application's main strengths, although further refinements are needed in audio stability, simplifying voice instructions, and alternative navigation options to optimize accessibility.

III. CONCLUSION

This study identified and analyzed the accessibility needs of visually impaired individuals in learning Arabic and successfully developed *Arabicara*, a mobile application designed to address those needs through an audio-based and cloud-supported learning approach. The findings indicate that traditional learning media such as Braille books, while helpful, remain limited in flexibility and in supporting independent study. Therefore, digital learning platforms that emphasize audio interaction and adaptability are crucial for promoting inclusive education. The *Arabicara* application integrates several accessibility-oriented features, including Text-to-Speech (TTS), consistent voice navigation, Optical Character Recognition (OCR) for Arabic text, a bilingual digital dictionary, and interactive audio quizzes. Evaluation through user testing demonstrated that these features significantly improved learning engagement and independence among visually impaired participants. Most users found the TTS and voice navigation systems intuitive and helpful, though some challenges persisted, particularly in audio clarity and dependence on internet connectivity. Based on these findings, this research concludes that integrating audio-centric features in mobile learning can substantially enhance accessibility for visually impaired learners and contribute to more equitable educational opportunities. Moving forward, further refinement is recommended to strengthen the system’s reliability and usability. Enhancing audio quality, minimizing latency, and optimizing performance for low-end devices will ensure smoother use across diverse conditions. Moreover, adding features such as offline access, voice recognition, and personalization of speech

settings can expand user autonomy and comfort. Future studies should also involve larger and more diverse participant groups to evaluate usability and learning outcomes comprehensively. Finally, continuous maintenance, regular updates, and strict data protection measures must be prioritized to maintain long-term sustainability and user trust.

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