



Navigating Interactive Web-Assisted Learning: A Case Study of Learners' Responses and Adaptive Strategies Using Automatic Speech Recognition and Text-to-Speech in Arabic Listening

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Abstract

The increasing integration of Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) in language learning has created new opportunities for improving Arabic listening instruction. However, previous studies have primarily focused on the technical effectiveness of these technologies and learning outcomes, while limited attention has been paid to learners' responses and the adaptive learning strategies that emerge during technology-mediated learning. This study investigates learners' responses and adaptive strategies when using an interactive web-assisted learning environment integrating ASR and TTS in Arabic listening instruction. A qualitative case study was conducted with 28 secondary school students in Malaysia over eight instructional sessions. Data were collected through questionnaires, semi-structured interviews, classroom observations, field notes, and learning activity records, and were analysed using the Miles and Huberman interactive model. The findings reveal that learners demonstrated positive responses, reflected in increased motivation, active engagement, and improved listening comprehension. They also developed adaptive strategies, including repeated audio playback, integrating visual and auditory information, and independently utilizing automated feedback to improve pronunciation and comprehension. The study contributes to the literature on Computer-Assisted Language Learning (CALL) by demonstrating that the pedagogical integration of ASR and TTS supports adaptive learning behaviours and learner autonomy. Furthermore, it extends the application of Cognitive Load Theory by showing how multimodal feedback can facilitate more meaningful and learner-centred Arabic listening instruction.

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Introduction

In the teaching of Arabic as a foreign language, the use of digital technology is becoming increasingly important, particularly in the area of listening skills (*mahārah al-istimā'*) (A'yun et al., 2026). This skill serves as the foundation for mastering speaking, reading, and writing, as the language acquisition process begins with the ability to receive and understand spoken language (Azka et al., 2024). However, listening remains one of the most challenging aspects for non-native learners (Wiboolyasarini et al., 2026). The complexity of the Arabic phonological system, the diversity of consonant sounds, the length of vowels, the speaking speed of native speakers, and limited vocabulary often cause learners to struggle with recognizing sounds, grasping key information, and fully understanding meaning (Almelhes, 2024). At the same time, teaching practices in various institutions are still dominated by the repetitive playback of audio recordings without any interaction or feedback that would allow students to identify their mistakes and correct them immediately (Altaikhaineh et al., 2024). These conditions result in listening instruction that tends to be passive and does little to encourage the development of independent learning strategies (Fatmawati et al., 2025).

The development of web-based learning media offers a more dynamic approach to addressing these issues (Widiaty et al., 2020). Unlike conventional audio media, interactive web-based learning allows learners to interact directly with the learning material through a combination of text, audio, visuals, and automated feedback (Zakia Jauharotul Munfarida et al., 2026a) (Yusuf & Ali, 2022). The integration of TTS technology enables Arabic text to be converted into natural-sounding speech, providing learners with a consistent pronunciation model, while ASR technology recognizes learners' spoken responses and provides real-time corrections (Obaida Chaqmaqchee & Omar Abbas Naithel, 2025; Zakia Jauharotul Munfarida et al., 2026b). The combination of these two technologies creates a more participatory learning environment because learners not only listen to the material but also actively respond, evaluate their mistakes, repeat exercises, and adjust their learning strategies based on the feedback they receive. Thus, listening instruction evolves from a receptive activity into an interactive process that supports self-directed learning (Sarbanan, 2024).

A number of studies indicate that the use of digital technology has a positive impact on Arabic language learning (Faiqoh et al., 2025). A systematic review of interactive multimedia reports that various digital platforms can enhance learning motivation, student engagement, vocabulary acquisition, listening skills, and comprehension of the material when designed in accordance with learning characteristics (Susiawati et al., 2025). More specifically, research on the use of TTS in *mahārah al-istimā'* instruction shows that this technology can provide more accurate pronunciation models and help

learners understand Arabic sounds more consistently (Auliya et al., 2025). On the other hand, research on the development of interactive web-based media using ASR and TTS reports that the integration of these two technologies can improve the quality of listening practice by providing automatic feedback, helping students identify phonological errors, and reducing the burden on teachers in performing manual corrections.

Research on interactive web-based media utilizing Automatic Speech Recognition (ASR) and Text-to-Speech (TTS), for example, has primarily focused on system design, the feasibility of the media, and improvements in listening skills following its use (Zuhriyah et al., 2026). In addition, various literature reviews on the integration of AI in Arabic language learning conclude that technology can enhance learning personalization, motivation, and learner autonomy; however, most of these studies remain conceptual and thus do not explain how the interaction between learners and technology takes place in real-world learning situations (Yan et al., 2025).

These limitations indicate that research on AI-assisted Arabic language learning is still dominated by technology-centered approaches rather than learner-centered ones (Li et al., 2025). As a result, there is still little research explaining how learners utilize automatic feedback from ASR, how TTS features help them build an understanding of spoken Arabic, and how their learning strategies change when they encounter difficulties during the listening process. In fact, the success of technology implementation is determined not only by the sophistication of the system but also by learners' ability to interpret feedback, reflect, and continuously adjust their learning strategies (Dr. A. Shaji George, 2023). A recent systematic review even shows that AI research in Arabic language learning still lacks empirical evidence linking technological capabilities to Second Language Acquisition (SLA) theory and learners' learning experiences (Muh. Sabilar & Fitria, 2026).

Previous studies have demonstrated that the integration of digital technologies, particularly ASR and TTS, provides valuable support for Arabic language learning by improving pronunciation practice, listening comprehension, and learner engagement. However, most existing studies have emphasized the development, technical performance, or effectiveness of technology-based media, while the process of how learners interact with these technologies and construct adaptive learning strategies remains underexplored (Ouyang et al., 2022; H. Qiao & Zhao, 2023; Wang et al., 2023). To address this limitation, the present study proposes a learner-centred approach that examines ASR and TTS as pedagogical tools that facilitate interaction between learners, learning materials, and automated feedback. Through a qualitative investigation of learners' experiences, this study seeks to provide empirical evidence on how students respond to interactive web-assisted learning environments and how they adapt their learning behaviours during Arabic listening activities. The findings are expected to strengthen the understanding of technology-mediated language learning by highlighting the relationship between technological affordances, learner autonomy, and adaptive strategies (Gligorea et al., 2023; Kaur et al., 2023; S. Qiao et al., 2025).

Given this gap, this study positions itself as a case study focused on the learning process, rather than merely an evaluation of the effectiveness of the media. This study views ASR and TTS not merely as technological features, but as pedagogical tools that shape the interaction between learners, instructional content, and feedback during Arabic listening instruction. Consequently, the research focuses on how learners respond to the use of interactive web-based tools and how they develop

Previous research indicates that Artificial Intelligence (AI)-assisted Arabic language learning is still dominated by technology-centered approaches, while learner-centered learning experiences have not received much attention. Most studies have focused on the effectiveness of the media, so they have not thoroughly explained how learners utilize automatic feedback from Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) to build comprehension and develop learning strategies during the listening process. In fact, the success of technology implementation is determined not only by the sophistication of the system but also by learners' ability to interpret feedback and adjust their learning strategies. Furthermore, AI research in Arabic language learning still requires empirical evidence linking technology use to the process of Second Language Acquisition (SLA).

Given this gap, this study is positioned as a case study focused on the learning process. ASR and TTS are viewed as pedagogical tools that support interaction among learners, learning materials, and feedback in Arabic listening instruction. Therefore, this study aims to examine learners' responses to the use of interactive websites and the adaptive strategies they develop when utilizing ASR and TTS features.

This study aims to answer two questions: (1) how do learners respond to the use of an interactive website based on ASR and TTS in Arabic listening instruction, and (2) what adaptive strategies do learners develop through the use of automated feedback during the listening process.

This study is limited to learners of Arabic as a foreign language who use interactive web-based media utilizing ASR and TTS for *mahārah al-istimā'*. The focus of the study is not on evaluating the technical performance of ASR or TTS, nor on measuring learning outcomes, but rather on the learners' responses, learning experiences, and adaptive strategies during their interactions with the media.

Theoretically, this study contributes to the field of Computer-Assisted Language Learning (CALL) and adaptive learning in Arabic language instruction by elucidating the relationship between automated feedback, learner responses, and adaptive strategies. Practically, the findings are expected to serve as a reference for teachers, instructional media developers, and curriculum designers in developing more interactive and learner-centered web-based listening activities.

The main contribution of this study is to provide empirical evidence regarding the process of learner interaction with interactive web-based media utilizing ASR and TTS. Unlike previous studies that focused on the effectiveness of the media, this study positions learners as the primary actors in developing learning strategies; it is therefore expected to

enrich the literature on AI-assisted Arabic language learning and support the development of media that are more adaptive and focused on the learning experience.

Method

This study employs a qualitative approach using a case study design to examine learners' responses and adaptive strategies during the use of interactive web-based media utilizing Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) in the teaching of *mahārah al-istimā'*. This design was chosen because it allows for the exploration of learning phenomena in a real-world context through the interaction between learners, technology, and the learning environment. The study is grounded in the concepts of Computer-Assisted Language Learning (CALL) and Adaptive Learning (Fan et al., 2020) (Ulfa et al., 2026). The research focuses on the learning process, particularly learners' responses to the use of interactive web-based media and the adaptive strategies that emerge during listening activities (Erdiana et al., 2025). The study was conducted at a secondary school in Malaysia that was selected through purposive sampling because it had already implemented web-based Arabic language learning (Osman et al., 2022). The unit of analysis was the learning experiences of 28 students selected through purposive sampling, with an Arabic language teacher serving as a supporting informant (Isnaini et al., 2026).

The research data consisted of primary and secondary data. Primary data were obtained through observation, semi-structured interviews, field notes, student reflections, and media activity logs, while secondary data were derived from instructional materials, listening exercise results, and relevant literature. Data collection took place over eight sessions using the *التعارف* (al-Ta'āruf) material. Students used the TTS feature to listen to the material and the ASR feature to provide responses, thereby receiving automatic feedback. During this process, the researcher observed the students' interactions with the media and conducted in-depth interviews with several students based on the variety of responses they demonstrated.

Data analysis was conducted using the interactive model proposed by Miles, Huberman, and Saldaña, which includes data condensation, data presentation, and the drawing and verification of conclusions. The data were coded, grouped into themes, and then interpreted to identify patterns of response and adaptive strategies among learners. Data validity was ensured through the criteria of trustworthiness according to Lincoln and Guba (1985) namely, credibility, transferability, dependability, and confirmability which were applied through triangulation of methods, member checking, detailed contextual descriptions, research process audits, and the provision of an audit trail.

This methodological approach differs from previous studies that have predominantly adopted quantitative designs to measure the effectiveness of ASR and TTS-based learning media or to evaluate improvements in language performance. While such approaches provide valuable evidence regarding learning outcomes, they provide limited explanations of how learners interact with technological features, interpret

automated feedback, and develop adaptive strategies during the learning process. Therefore, this study employs a qualitative case study design to capture learners' experiences and behavioural adaptations within an authentic instructional context. The combination of multiple data sources, including interviews, observations, field notes, and learning activity records, enables methodological triangulation and provides a more comprehensive understanding of learner-technology interaction. This approach strengthens the methodological contribution of the study by shifting the focus from technology effectiveness to the processes underlying adaptive learning in AI-assisted Arabic listening instruction.

Results and Discussion

4.1 Learners' Initial Responses toward Interactive Web-Assisted Arabic Learning

This study aims to explore students' initial responses to the use of an interactive web-based Arabic language learning tool that integrates Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) features. Based on the results of a questionnaire administered to 32 students after they participated in eight learning sessions, this study provides insights into students' perceptions of the difficulty of learning Arabic, their level of enjoyment during the learning process, and the ease with which they understood the material.

Tabel 1.

Students' Responses toward Interactive Web-Assisted Arabic Learning (n = 32)

Aspect	Category	Frequency	Percentage (%)
Level of difficulty in learning Arabic	Mudah	6	18.75
	Moderate	17	53.13
	Difficult	9	28.13
Enjoyment of using the media	Very enjoyable	17	53.13
	Enjoyable	8	25.00
	Fairly enjoyable	7	21.88
Ease of understanding the material	Very easy	5	15.63
	Easy	18	56.25
	Fairly easy	9	28.13

Most students (53.13%) consider learning Arabic to be of moderate difficulty, while 28.13% still find it difficult. Nevertheless, perceptions regarding the use of learning media show a very positive trend. More than half of the respondents (53.13%) stated that learning using interactive web-based media was very enjoyable, while 56.25% stated that

such media made it easier for them to understand the material. These findings indicate that although Arabic is perceived as a challenging language for beginner learners, the use of web-based media can create a more engaging learning experience and aid in the process of understanding the material..

4.2 Learners' Adaptive Strategies while Using Automatic Speech Recognition and Text-to-Speech

The interview data provides a more in-depth understanding of how students adapt when using learning media. The thematic analysis yielded four main themes: initial adaptation to Arabic language learning, utilization of multimedia features, strategies for overcoming difficulties, and increased motivation to learn.

Tabel 2.

Themes Generated from Interview Data

Theme	Indicator	Representative Quote
Initial Adaptation	Learning a new language	“This is my first time learning Arabic. At first, I found it difficult.” (S1)
Use of Multimedia	Audio and images help with learning	“I like this medium because it has pictures and sound.” (S3)
Adaptive Strategies	Repeat the audio to understand the vocabulary	“If I listen to it a few times, I understand it better.” (S1)
Motivation to Learn	Learning becomes more fun	“I want to keep learning using media like this.” (S5)

The interview results showed that most of the students were beginner learners who had never studied Arabic before. This situation caused them to feel anxious at the start of the course. One student stated that they found Arabic difficult because they had never studied it before, while another expressed concern about being unable to understand the material. These statements indicate that the adaptation process is a crucial stage in foreign language learning.

As the learning process progressed, the students' perceptions became more positive. Most participants stated that the combination of images, audio, and interactive exercises helped them stay focused during the learning process. Some students also explained that they used the strategy of replaying the audio several times when they encountered unfamiliar vocabulary. This strategy demonstrates self-regulated learning, in which students actively utilize the TTS feature to improve their understanding of the material.

The findings of this study provide further insight into the role of ASR and TTS beyond their technological functions. Previous research has generally demonstrated that speech recognition and speech synthesis technologies improve language learning outcomes by providing pronunciation models, corrective feedback, and additional opportunities for practice. However, these studies have mainly examined measurable improvements in language performance rather than the learning processes developed by students during technology interaction. The present study extends previous findings by showing that learners actively construct adaptive strategies through repeated listening, comparison between auditory and visual input, and independent use of automated feedback. This indicates that ASR and TTS function not only as instructional tools but also as mediating resources that encourage self-regulated learning and learner autonomy. From the perspective of Cognitive Load Theory, the combination of auditory input, visual support, and immediate feedback helps learners manage information processing demands during Arabic listening activities.

Nevertheless, some participants still had difficulty understanding the pronunciation of new vocabulary. These difficulties did not cause them to stop learning, but rather encouraged them to replay the audio until they understood the meaning of the conversation. This situation demonstrates that the medium provides an opportunity for self-paced learning, thereby reducing stress during the learning process.

At the end of the interview, nearly all participants said they wanted to continue learning using similar media. They also suggested that the media include more educational games, illustrations, and a variety of exercises to make the learning experience more engaging.

The research results show that web-based learning media integrating Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) received positive responses from students, both quantitatively and qualitatively (McCrocklin & Levis, 2026). Although most students still view Arabic as a language of moderate difficulty, they believe that the learning media enhances their comfort and ease in understanding the material (Akla, 2021). These findings indicate that perceptions of a language's difficulty level do not always correlate directly with the learning experience when students receive appropriate technological support (Muhammad Lutfi Asfihani & Hayyi Alawiyah Munidzar, 2025).

The interview data show that the adaptive strategies most frequently used by students were replaying the audio, linking sounds to visual illustrations, and following the exercises step by step. These strategies indicate that students do not merely passively receive information but also build understanding through a process of independent exploration (Ritonga et al., 2024). From the perspective of Cognitive Load Theory, presenting information through a combination of visual and auditory cues allows the

processing load to be distributed across two distinct cognitive channels, thereby reducing the memory load and enhancing learning efficiency.

In addition, the Text-to-Speech feature allows students to access consistent pronunciation models that can be replayed as needed (Sabri et al., 2026). Meanwhile, the Automatic Speech Recognition feature gives students the opportunity to practice pronunciation independently and receive immediate feedback (Ariyanti et al., 2021). The combination of these two features supports an adaptive learning process, as students can adjust the intensity of their practice according to their individual abilities.

The findings of this study are consistent with several previous studies that have reported that the integration of speech recognition and speech synthesis technologies can enhance students' motivation to learn, listening skills, and engagement in foreign language learning. However, this study makes a distinct contribution because it not only evaluates the effectiveness of the media but also reveals how students develop adaptive strategies when using interactive web-based media in the context of Arabic language learning.

The results of the study show that the integration of Automatic Speech Recognition (ASR) into web-based learning materials has a positive impact on students' adaptation process in learning Arabic. Based on interview results, most students felt more confident when practicing pronunciation because they could repeat the exercises independently until they achieved what they considered to be correct pronunciation. This feature not only helps improve pronunciation accuracy but also reduces the fear of making mistakes when speaking (Muhammad Lutfi Asfihani & Hayyi Alawiyah Munidzar, 2025; Shadiev et al., 2026). These findings expand upon previous research, which generally concluded that ASR contributes to improved speaking skills and pronunciation accuracy. In this study, ASR also served as a tool that encouraged the development of adaptive learning strategies, in which students actively evaluated and corrected their pronunciation through repeated practice (Muhammad Lutfi Asfihani & Hayyi Alawiyah Munidzar, 2025).

In addition, the use of Text-to-Speech (TTS) has been shown to help students better understand listening material. Interview data indicate that students frequently use the audio replay feature when they encounter vocabulary or expressions they do not yet understand. This strategy allows students to learn at their own pace without relying entirely on the teacher's explanations. These results are consistent with various previous studies reporting that TTS can improve the ability to understand native speakers' pronunciation and strengthen listening skills. However, this study provides more in-depth findings by demonstrating that TTS also supports self-paced learning, giving students the opportunity to build their understanding through a process of repeated exploration.

Other findings indicate that interactive web-based learning media can enhance students' motivation, attention, and active participation during the learning process. Survey results show that most students found the learning experience more enjoyable, while interview results revealed that the combination of images, audio, interactive exercises, and immediate feedback helped them stay more focused during the learning process. These findings reinforce the results of previous research stating that web-based learning media can increase learning motivation. However, this study shows that the integration of ASR and TTS results in a more adaptive learning experience because students not only passively receive material but are also engaged in the learning process through exercises, repetition, and reflection on their own learning outcomes.

Overall, this study offers a distinct contribution compared to previous research. Most prior studies have focused on the effect of ASR on speaking skills or the effect of TTS on listening skills in isolation. This study, however, integrates both technologies into a web-based learning platform and explores how learners respond and develop adaptive strategies during the Arabic language learning process. Thus, the main contribution of this study lies not only in the effectiveness of learning technologies but also in the understanding of learners' adaptation processes when utilizing digital technologies to create a more independent, interactive, and meaningful learning experience.

Overall, the research findings indicate that web-based learning media that integrate Automatic Speech Recognition and Text-to-Speech not only enhance students' learning experiences but also foster the development of adaptive learning strategies through audio repetition, independent exploration, and the use of immediate feedback. These findings expand upon previous research by demonstrating that the successful implementation of language learning technology is determined not only by the features it offers but also by students' ability to develop learning strategies that align with the characteristics of the media used

Conclusion

In conclusion, pronunciation errors among orphanage students at the Banyuanyar Islamic Institute are heavily concentrated on unique Arabic phonemes that lack direct equivalents in Madurese and Indonesian—most notably the letters Qaf, Zha, Tha, and Sad. These errors stem from structural difficulties in executing distinct phonetic attributes such as *Isti'la*, *Itbaq*, *Shiddah*, and *Jahr*. The theoretical implications of these findings enrich Arabic applied linguistics and contrastive phonology by demonstrating how localized mother-tongue interference interacts with disparate educational backgrounds within a closed residential sub-unit, revealing that phonetic deviations risk permanent cognitive fossilization across multiple academic levels if systematic diagnostic intervention is absent.

Practically, this study underscores the necessity for non-formal educational bodies to transcend generalized reading methods. Instead, institutions must implement structured, intensive articulation models—such as the Halaqah Tahsin al-Quran—that couple repetitive muscular habituation with targeted psychological motivation to effectively dismantle non-linguistic barriers like low self-confidence and physical fatigue among vulnerable student demographics. To advance the findings of this study, future research should focus on two specific directions: First, Longitudinal Acoustic Analysis: Future studies should employ a longitudinal approach utilizing specialized speech analysis software (such as Praat) to objectively measure and track the exact acoustic timelines of phonetic error dissipation or fossilization among institutionalized students over an extended academic period. Two, Comparative Experimental Designs: Researchers are encouraged to implement comparative experimental studies to scientifically evaluate the efficacy of digital audio-visual articulatory media versus traditional peer-assisted learning circles specifically in mitigating heavy articulation errors (Isti'la and Itbaq) among non-native Arabic speakers.

Declaration of AI and AI-Assisted Technologies in the Writing Process

In the preparation of this manuscript, the authors utilized ChatGPT, Grammarly, and DeepL Translator to assist with language refinement, grammar checking, translation, and improvement of academic writing clarity. All outputs generated through these tools were carefully reviewed, verified, and revised by the authors. The authors take full responsibility for the accuracy, originality, and final content of the manuscript.

Author Contribution Statement

Rizky Aulia Nur Salsabila contributed to the conceptualization, data collection, analysis, and preparation of the manuscript. Asep Sunarko contributed to research supervision, methodological guidance, and manuscript review. Fatkhurrohman contributed to theoretical framework development, data interpretation, and manuscript refinement. Muhammad Adieb Aqasha contributed to research validation, critical review, and final editing of the manuscript.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Access to the data may be provided for academic and research purposes while maintaining participant confidentiality and ethical considerations.

Declaration of Interests

The authors declare that there are no financial, personal, professional, or other competing interests related to this study.

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