Volume 6 Number 1 (2025)
January-June 2025
Page: 85-96

E-ISSN: 2722-6794
P-ISSN: 2722-6786
DOI: 10.37680/aphorisme.v6i1.7144

APHORISME
Journal of Arabic Language, Literature, and Education
مجلة اللغة العربية أدبها وتعليمها

Integration of AI-Based Text-to-Speech Technology in Arabic Listening Skills Learning

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Submitted: 12/10/2024 Revised: 28/12/2024 Accepted: 09/02/2025 Published: 17/04/2025

Abstract

The advancement of modern technology has brought significant innovations in the field of education. One of the most developed technologies is AI-based Text-to-Speech (TTS), which converts written text into natural, accurate speech. This technology effectively solves the challenges students face in developing listening skills (maharah istima'). This research analyzes the potential, challenges, and strategies in integrating AI-based TTS into Arabic language learning, particularly in enhancing maharah istima'. The study uses a qualitative approach with a library research method. Data sources are obtained from relevant and up-to-date scientific literature, including journal articles, books, proceedings, and research reports. The collected data is analyzed using a thematic analysis approach. The findings show that AI-based TTS can improve the effectiveness of learning maharah istima' in Arabic, offering greater accessibility and flexibility. However, further development is needed to address limitations such as prosody, dialect, and the application of tajwid. One of the key strategies is implementing deep learning models in TTS.

Keywords AI; Arabic Language Learning; Deep Learning; Listening Skills; Text-to-Speech.

INTRODUCTION

The advancement of modern technology has been growing rapidly. The use of technology in education has introduced various innovations, one of which is the Text-to-Speech (TTS) learning medium based on Artificial Intelligence (AI). TTS is a natural language processing system that automatically converts written language into spoken language (Mubarak & Santoso, 2023). TTS also enables the conversion of written text into speech that sounds like human pronunciation, with AI supporting Arabic language learning through applying Natural Language Processing (NLP) (Mulyanto et al., 2024; Sarif & Amran, 2024). This technological innovation is crucial in enhancing the quality of education, especially in language learning (Maulani et al., 2022).

In this context, using Text-to-Speech (TTS) in Arabic language learning, particularly in developing listening skills, becomes increasingly relevant. Given the complex phonetic structure of Arabic, this technology has the potential to serve as a solution for students to overcome difficulties in listening and understanding the pronunciation of words in Arabic (Sanwil et al., 2021). The technology provides a consistent and accurate pronunciation model, allowing students to listen to words with the correct pronunciation repeatedly, thus facilitating independent practice of listening and pronunciation (Fauzan & Hartati, 2018; Mulyanto et al., 2024).

Listening skills must be mastered in Arabic language learning (Syamaun, 2016; Azmi & Puspita, 2019; Ariska, 2020). This skill includes listening well and understanding the meaning of words heard or spoken by the speaker to their conversational partner, either through direct speech or through media (Mufidah et al., 2019). Arabic learners will have difficulty understanding written and spoken texts without strong listening skills. Since listening skill is the first skill to be mastered (Baroroh & Rahmawati, 2020; Karomah & Al Anshory, 2022).

However, many students face challenges or difficulties in developing their listening skills (Sarif & Amran, 2024). One of the main challenges in Arabic language learning is the limited availability of quality audio materials that provide correct pronunciation by the rules of aswat ‘arabiyyah, which includes phonetics (pronunciation of letters or phonemes, makhrajul huruf, vowel and consonant sounds), intonation, prosody, as well as accent and dialect (Fauzan & Hartati, 2018; Mulyanto et al., 2024; Ikhwan & Aan, 2025). Many educational institutions provide audio recordings or use face-to-face teaching, but the flexibility and accessibility are limited. AI-based TTS can offer a solution by providing audio access that can be replayed anytime and anywhere, enriching the learning experience and facilitating repetition of pronunciation based on students' needs (MR, 2024;

Pertiwi, 2024).

Although TTS holds great potential, its application in Arabic language learning still faces several challenges. One of these challenges is the limitation in processing prosody (intonation) and recognizing various dialects in Arabic (Amri, 2022). For example, Arabic has a wide variation in pronunciation, both between dialects used in Arab countries and the standard pronunciation used in teaching. The current TTS systems may not accurately accommodate these differences, which can hinder the effectiveness of the technology in learning (Andayu, 2013; Mulyanto et al., 2024). Additionally, there is still a lack of understanding of tajwid and phonetic rules in TTS systems. While TTS can produce clear and natural-sounding speech, existing applications cannot fully replicate all aspects of tajwid, which are essential in learning listening skills learning. Therefore, further development in technical aspects, such as applying deep learning models to improve pronunciation accuracy, is needed for TTS technology to be more effective in supporting Arabic language learning (Siswanto et al., 2023). The application of deep learning in the context of Text-to-Speech (TTS) refers to the use of more advanced machine learning algorithms, particularly those based on neural networks, to improve pronunciation quality in the TTS system (Andayu, 2013; Lutfiyatun et al., 2023).

Several previous studies have shown that TTS technology positively impacts language development. Fauzan (2018) presented test results showing that the TTS system using the diphone concatenation technique produces speech that complies with tajwid reading rules in most cases. Some readings had a high accuracy rate (100%), such as idghaam and sukun, while others had lower accuracy (65%-81%). Mubarak (2023) noted that students had a positive perception of using the text-to-speech application (narakeet.com) in Arabic language learning, receiving a good rating.

Mulyanto (2024) also explained that there was a significant improvement in listening skills, particularly in pronunciation, intonation, and overall understanding among participants using AI-based TTS. Sarif (2024) emphasized that AI TTS improved reading skills by producing clear and accurate speech, helping listeners understand and replicate pronunciation accurately. Furthermore, Amadi (2025) highlighted that the use of AI technology in Arabic language learning has a positive perception, particularly in assisting with translation and pronunciation (Amadi & Hikmah, 2025).

Based on the above state of the art, the novelty of this study lies in the conceptual study of the integration of AI-based TTS in listening skill learning (potential, challenges, and strategies). Based on this state of the art and novelty, this study aims to analyze how AI-based TTS can be

integrated into Arabic language learning, particularly in developing listening skills. The study will also examine the challenges faced in implementing this technology and the strategies that can be used to overcome these barriers. This research is expected to significantly contribute to developing more effective and adaptive learning methods in higher education, particularly in Arabic language learning. Additionally, the results of this study can serve as a reference for developing more effective AI-based learning applications that meet the needs of Arabic language learners at various educational levels.

METHOD

This study uses a qualitative approach with the library research method. This approach was chosen because the main focus of the study is to analyze the potential, challenges, and strategies for implementing Text-to-Speech (TTS) technology based on Artificial Intelligence (AI) in developing listening skills in Arabic language learning (Huang et al., 2023; Mulyanto et al., 2024; Amadi & Hikmah, 2025). Data sources were obtained from relevant scientific literature, including journal articles, books, proceedings, and research reports published within the last five years. The sources were selected based on topics related to AI-based TTS, Natural Language Processing (NLP), and their use in Arabic language learning, particularly in language skill development. Studies from other languages were also included as a comparison (Fauzan & Hartati, 2018; Kumar et al., 2023; Mulyanto et al., 2024).

The data was collected by searching various academic databases and reputable international journals. The selected articles had high relevance to the focus of the research, which is the utilization of TTS in Arabic language teaching. Additionally, studies discussing the potential and challenges of using TTS in learning other languages were also analyzed to enrich the perspective. The data obtained were analyzed using a thematic analysis approach by identifying and grouping the main themes emerging from the literature. These themes include the potential of TTS in improving listening skills, the challenges of technology implementation, and strategies to address barriers that might be encountered in practice. Findings from various sources were then synthesized conceptually to provide a comprehensive understanding of the role of TTS in Arabic language learning (Kumar et al., 2023; Mulyanto et al., 2024).

To ensure the validity and reliability of the data, the results of the synthesis were compared with established theories and findings from previous studies. Verification was conducted to ensure

alignment between the literature used and the current state of development in TTS technology.

FINDINGS AND DISCUSSION

Findings

Based on the literature review from relevant previous studies, the following findings were obtained.

Table 1. Table Results of Literature Synthesis

No	Author(s)	Year	Title	Key Findings	Strengths	Weaknesses
1	Achmad Fauzan, Sri Hartati	2018	Text to Speech for Arabic Language Using Diphone Concatenation	The TTS system using diphone concatenation technique produces speech with correct tajwid rules for most cases. Accuracy is high (100%) for idghaam and sukun but lower (65%-81%) for other readings.	• TTS uses phoneme and diphone concatenation technique, producing more natural-sounding speech. • Can accommodate Arabic pronunciation rules, including tajwid.	• Speech quality varies depending on text type and pronunciation rules applied. • Testing shows lower accuracy for texts with complex vowel combinations and long readings.
2	Muhammad Husni Mubarak, Agung Budi Santoso	2023	Student Perceptions of Using Text-to-Speech Applications in Arabic Language Learning Technology Courses	Students have a positive perception of using text-to-speech (TTS) applications in Arabic language learning courses. They find that the application helps them understand Arabic texts.	• Eases the understanding of pronunciation and vocabulary in Arabic. • Narakeet.com application offers various voice options and useful file formats.	• The application is only available online, requiring a stable internet connection. • Limited ability to handle variations in dialectical speech.
3	Dedi Mulyanto, Muhammad Wahyudi, Arsyad Muhammad Ali Ridho, Muhammad Zaki	2024	Utilization of Artificial Intelligence with Text-to-Speech Technology Based on Natural Language Processing to Enhance Arabic Listening Skills for	AI-based TTS supported by NLP improves Arabic listening skills for non-native speakers by producing clear and accurate speech. This enhances listening comprehension, pronunciation, and intonation.	• Improves listening comprehension with accurate and consistent pronunciation. • Provides a more interactive and personalized learning experience. • Uses advanced NLP techniques to improve the	• Limited in handling a wide range of dialects. • Requires further development to produce more natural and realistic speech.

			Non-Native Speakers		quality of speech output.	
4	Suharia Sarif, Amran AR	2024	Effectiveness of Artificial Intelligence Text-to-Speech in Enhancing Reading Skills	AI TTS is effective in improving reading skills by producing clear and accurate speech, helping listeners understand and replicate the pronunciation correctly.	• Provides assistance in correct pronunciation, especially for beginners. • Uses AI TTS to support more effective Arabic language learning.	• The effectiveness of AI TTS compared to traditional teaching methods has not been fully studied. • Still limited in addressing more complex tajwid rules.
5	Aunur Shabur Maajid Amadi1, Khizanatul Hikmah	2025	Student Perceptions of the Utilization of AI Technology in Arabic Language Learning in Indonesian Islamic Universities	Students in the Arabic Language Education Program at the University of Muhammadiyah Sidoarjo view AI technology, particularly ChatGPT, as an effective tool in Arabic language learning, especially for translation and pronunciation.	• Increases student motivation. • Provides easier access to various learning materials. • Helps with translation, pronunciation, and idea development.	Limited in addressing deeper linguistic aspects, such as grammar mastery and understanding classical Arabic texts.

The table 1 above presents the results of a literature synthesis related to using AI-based Text-to-Speech (TTS) technology in Arabic language learning, focusing on improving listening skills (maharah istima'). In general, all studies indicate that AI-based TTS has the potential to enhance the Arabic learning experience by providing clearer pronunciation and helping students understand Arabic texts. However, several challenges need to be addressed, such as dialect variations, complex tajwid pronunciation, and the development of more natural-sounding speech.

AI-based TTS can be a highly effective tool, especially with the application of advanced NLP and deep learning techniques. Nevertheless, further development is required to address existing limitations, including the ability to handle dialect variations and improve the realism of speech quality. This remains a key challenge in the development of TTS technology for Arabic language learning.

Discussion

Based on the table above, AI-based Text-to-Speech (TTS) technology has great potential to enhance maharah istima' (listening skills) in Arabic language learning. One of the main advantages of this technology is its ability to convert written text into speech that sounds natural and accurate. This is highly relevant in Arabic language learning, which has a complex phonetic structure and often poses a challenge for students wanting to master listening skills (Sulaiman, 2023; Mulyanto et al., 2024; Syifaunnufus, 2024). AI-based TTS allows pronunciation that adheres to phonetic rules such as makhrajul huruf (articulation points of letters), vowel and consonant pronunciation, and correct intonation. The use of this technology provides students with the opportunity to repeatedly listen to accurate pronunciations, which is crucial for independently mastering maharah istima'. Students can listen to words or phrases repeatedly until they have mastered the correct pronunciation without direct teacher assistance (Fauzan & Hartati, 2018; Sarif & Amran, 2024).

This is consistent with the research conducted by Andayu et al. (2021), which states that the TTS engine they developed can produce Arabic speech by phonetic rules. Another advantage of TTS is its flexibility: it can be accessed anytime, allows for repeated audio playback, and supports independent learning. Mubarok (2023) added that students felt helped in recognizing intonation, sound length, and articulation, especially in pronouncing difficult hijaiyah letters. The learning experience becomes more interactive and enjoyable. By integrating TTS technology, the Arabic learning process is not solely dependent on teachers or limited recordings, but opens up to dynamic and adaptive AI-based technology.

Furthermore, AI-based TTS provides high accessibility for students. In learning environments constrained by time and space, this technology allows students to access pronunciation materials anytime and anywhere, and repeat them according to their needs. This is especially helpful for students who do not have direct access to face-to-face teaching or native speaker recordings that meet the standards (Pertiwi, 2024). Thus, AI-based TTS enriches the Arabic learning experience and supports independent learning for students. This is in line with the research by Fitria and Susanti (2022), which also explained that the use of TTS in English language learning at the elementary level has a positive impact on pronunciation and vocabulary acquisition.

Although AI-based Text-to-Speech (TTS) technology offers great potential in maharah istima' (listening skills) learning, particularly in enhancing students' listening comprehension, several challenges need to be addressed for its implementation to be more effective and optimal. These

challenges include limitations in prosody processing, dialect recognition, and the integration of tajwid rules in TTS systems.

One of the main challenges in applying TTS in listening skill learning is the limitation of the technology in processing prosody or intonation. Arabic, a language rich in intonation variations, has meanings that can change dramatically based on intonation (Senen, 2017; Hanifah, 2023; Mulyani et al., 2023). For example, a sentence spoken with different intonation can alter its meaning significantly. Current TTS technologies still struggle to fully capture these prosodic nuances, which can affect the quality of learning, particularly in aspects that require understanding differences in intonation and word meaning (Andayu, 2013).

Additionally, another challenge that needs to be addressed is the use of diverse dialects in the Arabic language. Arabic has various dialects that vary significantly across regions, each with distinctive phonetic characteristics. This phenomenon poses a major challenge for TTS technology because although TTS systems can produce accurate speech in Modern Standard Arabic (MSA), these systems often fail to replicate or capture the nuances of local dialects. Maulana and Fadhilah (2020) revealed that the diphone concatenation technique used by many TTS systems is still unable to produce natural-sounding speech, often resulting in monotony and lack of expressiveness, which ultimately affects students' listening comprehension.

In addition to technical issues, another challenge is the level of technological skills among educators. Although TTS technology holds great potential, not all teachers have sufficient understanding or skills to utilize this technology in teaching effectively. Syifa and Pradita (2023) emphasize the importance of digital literacy for educators to effectively use technology-based learning tools, including TTS and voice changer applications. Without adequate training, using TTS technology could be ineffective or counterproductive in enhancing students' competencies. Therefore, it is crucial to provide proper training for educators to ensure that TTS technology can be used effectively to improve students' learning outcomes.

Several strategies can be applied to overcome these challenges in developing AI-based TTS technology. One of the main solutions is the implementation of deep learning in the development of TTS systems. The application of deep learning models in Arabic Text-to-Speech (TTS) systems has led to significant improvements in pronunciation quality, speech naturalness, and linguistic context understanding (Kumar et al., 2023). The detailed explanation is as follows:

1. Improvement in Pronunciation Accuracy

   Deep learning models enhance the accuracy of diacritics (harakat), which is crucial for Arabic pronunciation. Neural networks such as RNNs and Transformers are capable of processing sentence context to predict diacritics with lower error rates (DER 5.3% on the Tashkeela corpus) (Lameris, 2021).

2. Recognition of Complex Phonetic Patterns

   Deep neural networks excel at recognizing unique Arabic phonetic patterns, such as:

   a. Pronunciation of guttural letters (ع, غ, ق) that do not exist in other languages.
   b. Variations in double vowels and tanwin.
   c. Rules of tasydid (gemination) and ta marbutah.

   Studies using Tacotron and HiFi GAN demonstrate the model's ability to capture audio spectrograms with an accuracy of 3.66/5 in naturalness evaluation (BETTAYEB et al., n.d.; Fauzan & Hartati, 2018).

3. Prosody and Intonation Optimization

   RNN-based prosody generators (as seen in Mansour's research) produce more natural pitch contours and word stress by considering:

   a. Sentence structure (declarative vs. interrogative).
   b. The position of words in a phrase.
   c. Rules for the length of sounds (madd).

4. Integration of Contextual Language Models

   Transformers and attention mechanisms allow models to understand the relationships between words in long sentences. Examples include:

   a. Disambiguating homographs (words with the same spelling but different meanings) through context-based diacritics.
   b. QCRI combines morphological analysis and machine translation to produce coherent speech.
   c. The use of the Tashkeela corpus (which contains religious texts) and the Wiki News corpus (MSA news) enhances the model's adaptation to modern language varieties (Lameris, 2021).

This advancement demonstrates the potential of deep learning in addressing the complexities of the Arabic language, although challenges such as the need for modern diacritic data and the handling of loanwords still require further development. By using deep learning, TTS technology can produce speech that more accurately follows Arabic phonetic rules and respond

better to students' needs in recognizing correct pronunciation.

Another important strategy is the development of TTS systems that can recognize variations in Arabic dialects. By using a wider and more diverse dataset, deep learning models can generate more flexible pronunciation that aligns with the dialectical variations across the Arab world. This would allow students from various cultural backgrounds to receive a learning experience that is more relevant and tailored to their needs (Kumar et al., 2023). Furthermore, developing TTS applications that facilitate direct interaction between students and the technology is crucial. Such applications can provide immediate feedback on students' pronunciation, helping them correct their mistakes independently. Features like pronunciation repetition and adjustments based on tajwid will enhance learning effectiveness and allow students to practice their skills more intensively (Amadi & Hikmah, 2025).

By considering the potential and challenges involved and implementing these strategies, AI-based TTS technology is expected to further support the learning of maharah istima' in Arabic, providing a more effective, flexible, and responsive learning experience that meets the needs of students at various educational levels.

CONCLUSION

The integration of AI-based Text-to-Speech (TTS) technology in Arabic language learning, particularly for developing listening skills, holds great potential to improve the quality of learning. TTS allows students to listen to the accurate and consistent pronunciation of words, while providing flexibility in independent learning that can be done anytime and anywhere. This technology helps students overcome pronunciation difficulties and understand the complex phonetics of the Arabic language, thereby supporting the development of listening skills. However, applying TTS in Arabic language learning still faces several challenges, such as limitations in prosody processing and recognition of various Arabic dialects. In addition, the current TTS technology is not yet fully capable of accommodating tajwid rules, which are critical in Arabic language learning. Therefore, this article synthesizes new findings as strategies to overcome existing challenges by recommending the development of TTS based on deep learning for phonetic and tajwid need.

Next, practical recommendations for teachers include integrating AI-based TTS in lessons, particularly for teaching tajwid and pronouncing difficult Arabic letters. For application developers, it is essential to improve pronunciation accuracy according to Tajwid rules, address dialectal

variations in Arabic, and develop applications that can accommodate these differences. Additionally, using more advanced deep learning technology to produce more natural and contextual speech and providing an offline version would allow the application to be used without a stable internet connection. Future researchers are encouraged to develop deep learning models in TTS applications further.

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