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Analyzing Phonetic Errors Among Non-Native Arabic Learners Through Artificial Intelligence

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Abstract

Accurate pronunciation is essential for non-native Arabic learners, yet many face persistent difficulties in articulating specific sounds, leading to phonetic errors that impede comprehension. With technological advancements, artificial intelligence (AI)—particularly Automatic Speech Recognition (ASR)—offers promising solutions for identifying and correcting such errors. This study explores the application of AI in analyzing phonetic inaccuracies among Arabic learners through an experimental model using ASR technology. Employing a descriptive-analytical approach, ten undergraduate students from Universitas Islam Negeri Sumatera Utara were asked to read short Arabic passages. Their recordings were processed through ASR to detect pronunciation errors, including sound substitution, weak articulation, and inaccuracies in elongation (*madd*) and nasalization (*ghunnah*). The results demonstrate that ASR effectively identifies recurring phonetic error patterns, providing instructors with valuable diagnostic insights and enabling timely, personalized feedback. The study concludes that integrating AI-driven pronunciation analysis into Arabic language instruction can significantly enhance learning outcomes, support autonomous practice, and promote more accurate oral proficiency. It recommends that educators and institutions adopt ASR-based tools as part of digital language pedagogy to strengthen pronunciation training and foster continuous learner engagement.

Keywords: *artificial intelligence, automatic speech recognition technology, phonetic error analysis*

Introduction

The ability to accurately articulate linguistic sounds is a fundamental skill that must be possessed by Arabic language learners, particularly those specializing in the teaching of Arabic to non-native speakers (Nasution, 2017). However, empirical observations reveal a striking issue among students in the Arabic Language Education Department at the Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri (UIN) Sumatera Utara, Medan; many students struggle to pronounce Arabic sounds and letters correctly. Ironically, these students are enrolled in a program specifically designed to prepare them as Arabic language educators, which exacerbates the problem and poses long-term implications for their professional performance and educational outcomes.

This issue is attributed to several factors, the most prominent being the diverse educational backgrounds of the students (Nasution, 2021). A significant number of them come from general education settings, such as public high schools, or religious education backgrounds (Nasution et al., 2025), which do not emphasize in-depth instruction in Arabic language (Keysha et al., 2023). As a result, their linguistic competence, particularly in pronunciation and phonetic articulation, tends to be limited. Furthermore, phonetic error correction is often carried out using traditional methods that rely on teacher intervention or peer feedback. While these approaches can be helpful, they are often subjective and inconsistent, and may not be sufficient to address pronunciation errors in a systematic and comprehensive manner.

In this context, there emerges an urgent need to harness modern technological advancements (Nasution et al., 2024), particularly artificial intelligence (Alsaawi et al., 2025), as an effective and objective solution for monitoring phonetic errors among learners. Artificial intelligence possesses the capability to analyze speech with high precision and to deliver instant, automated feedback to students, enabling them to independently and repeatedly improve their pronunciation without requiring constant supervision from instructors. This represents a significant leap forward in pronunciation instruction, as it allows learners to practice anytime and anywhere, thereby enhancing autonomous learning and boosting their confidence in using spoken Arabic.

Recent studies have highlighted the importance of integrating artificial intelligence into language instruction (Sapawi & Yusoff, 2025), including the teaching of pronunciation. Several technologies have proven effective in this context, such as Speech-to-Text systems, Pronunciation Assessment Tools, Automatic Speech Recognition (ASR) software, and Phonetic Simulation Tools. These technologies enable learners to compare their pronunciation with native speaker standards, thereby supporting more accurate and consistent phonetic development (Ahlawat et al., 2025).

Modern technology, particularly artificial intelligence, has become one of the key tools contributing to the advancement of Arabic language instruction (Bin Subait et al., 2025, Alkaabi & Almaamari, 2025) for non-native speakers (Nasution et al., 2024). One of the most significant applications in this field is ASR technology (Balula et al., 2021). ASR converts spoken language into written text with high accuracy, utilizing linguistic algorithms and machine learning models (Alhanai & Glass, 2014; Alsayadi et al., 2021; Dhouib et al., 2022). The importance of ASR in Arabic language education lies in its ability to facilitate real-time oral interaction, diagnose learners' pronunciation errors, and support the development of both pronunciation and listening comprehension skills.

The technology is equipped to recognize a wide range of sounds, distinguish between similar phonemes, and analyze speech output at the letter and syllable levels. Its implementation involves recording the learner's voice, processing it through ASR, generating a linguistic analysis, and providing appropriate feedback. The main advantages of this technology include its accuracy, speed, and efficiency in saving time and effort for both teachers and learners. However, its limitations include the need for extensive linguistic data to train the models and challenges in distinguishing certain dialects or unclear speech. Nevertheless, ASR represents a groundbreaking innovation

in Arabic language pedagogy and holds great potential for further exploration and development (Wilschut et al., 2024).

As highlighted in the study titled "The use of speech recognition technology and artificial intelligence can significantly contribute to identifying and correcting pronunciation errors among foreign language learners," Shannon (2016) further explains that "this study demonstrates that the use of ASR in pronunciation training can significantly enhance learner autonomy." For instance, learners who were given access to ASR technology spent more time engaging in independent practice and reported increased confidence in improving their pronunciation without relying on teacher intervention.

Xiao and Park reported that ASR technology has proven effective in diagnosing pronunciation errors among learners of English as a foreign language, achieving an accuracy level nearly equivalent to that of expert human evaluators, particularly at the phonemic level. This technology also contributes significantly to addressing various learner needs in pronunciation instruction.

According to Sun (2023) in Frontiers in Psychology, ASR technology directly contributes to the improvement of speaking and pronunciation skills among foreign language learners, reaching statistically significant levels of enhancement through instant audio and visual feedback. In summary, the study demonstrates that ASR technology provides immediate feedback, fosters learner autonomy, and significantly supports the development of accurate pronunciation.

This study contributes to addressing a research gap within the Indonesian context, where investigations into the integration of artificial intelligence in Arabic phonetic instruction remain limited, particularly those focusing on the analysis of phonetic errors using modern technological tools. It also represents a continuation of global efforts to leverage intelligent technologies in language education, while offering specialized and objective characteristics in the assessment of learners' phonetic performance.

This study aims to analyze common phonetic errors among students in the Arabic Language Education Department at the UIN Sumatera Utara by utilizing artificial intelligence tools to accurately identify error patterns and propose appropriate corrective models. The research involves the application of ASR technology to a sample of ten students, whose phonetic data were collected through targeted pronunciation tasks and subsequently processed using advanced AI-based systems. The study also seeks to demonstrate the effectiveness of this technology in facilitating pronunciation correction and enhancing students' oral proficiency, while exploring the extent to which learners accept and engage with such technology in their learning journey. Accordingly, this research aspires to offer practical and field-based recommendations to educational institutions, contributing to the improvement of Arabic language instruction and supporting the digital transformation of Arabic pedagogy in the modern era.

Method

This study employs a qualitative descriptive approach aimed at illustrating how learners utilize ASR technology to analyze phonetic errors in their Arabic pronunciation. This methodological choice aligns with the nature of the research, which seeks to understand linguistic phenomena through observation and analysis within real-world contexts, without relying on quantitative measurements or statistical generalizations. According to (Creswell, 2015; Creswell & Poth, 2016), qualitative research focuses on interpreting meaning and experience through rich, descriptive data.

Artificial intelligence technology known as ASR was selected as a modern tool capable of analyzing speech and determining its accuracy based on algorithms powered by machine learning. This technology is increasingly utilized in the field of language education, and Xiao and Park emphasize that ASR can diagnose pronunciation errors among learners of English as a foreign language with an accuracy level that closely approximates human expert evaluation, particularly at the partial phonetic level.

This study was conducted with ten students from the Arabic Language Education Program, Faculty of Tarbiyah and Teacher Training, UIN Sumatera Utara. The participants were purposively selected based on criteria related to their level of study and voluntary participation in the experiment. This sample size is considered appropriate for qualitative research, which does not require large numbers of participants but rather emphasizes depth in data collection and analysis.

The data collection methods in this study included direct observation, in which students' performance was monitored as they read selected Arabic texts aloud, and their pronunciation was recorded using an ASR application. Interviews were conducted with the students after the experiment to gather their reflections on the experience of using artificial intelligence tools, the challenges they encountered, and the benefits they perceived. The ASR trial was conducted using a portable computer device, where students completed designated pronunciation tasks, and the program recorded and analyzed their speech output.

Data analysis was conducted through the following steps: open coding, in which data from recordings and interviews were transcribed and recurring error patterns were identified; content analysis, where ASR results were compiled and compared with the researcher's manual notes to determine types of phonetic errors such as substitution, omission, or addition; and thematic interpretation, in which findings were organized into semantic themes that explain how and why these errors occurred, as well as the contextual factors contributing to their emergence.

Data validation was carried out through participant verification, in which summaries of the analysis were presented to the participating students to ensure accuracy and faithful representation of their experiences. Triangulation was conducted by integrating the results of observation, interviews, and ASR data analysis to obtain a comprehensive and accurate picture. Peer review was also employed, involving two fellow researchers in the field of Arabic language education who examined the analysis results to ensure objectivity and minimize bias.

This analytical method, along with the use of various artificial intelligence tools and data collection techniques, represents an integration of technology and educational research, enhancing the scientific rigor and credibility of the study's conclusions.

Result and Discussion

Steps for Implementing ASR Technology in Arabic Phonetic Instruction

Field research conducted with ten students from the Arabic Language Education Program at UIN Sumatera Utara revealed that the use of ASR technology in Arabic phonetics instruction significantly contributed to diagnosing phonetic errors, particularly at the level of individual syllables. This technology was implemented through a series of structured educational steps as follows:

The implementation of ASR technology in Arabic phonetic instruction followed four structured steps:

1. Phonetic Reading Task

Students were asked to read a series of Arabic words and sentences aloud, containing challenging phonetic variations such as guttural sounds, hamzah, emphatic consonants, and weakened articulations. These texts were specifically designed to align with the objectives of phonetic analysis.

2. Voice Recording and Automated Analysis

Students' voices were recorded using an ASR-integrated program equipped with pronunciation analysis algorithms. The recorded data were automatically processed to generate instant feedback, pinpointing the location of errors and suggesting corrective measures.

3. Individual Feedback Sessions

The analysis results were presented to students in one-on-one sessions, accompanied by teacher explanations regarding the types of phonetic errors, such as mispronunciation of letters, articulatory features, or duration of sounds. This interaction deepened students' phonetic awareness and facilitated self-review and performance correction.

4. Semi-Structured Interviews

Semi-structured interviews were conducted to gather students' perspectives on the effectiveness of the technology. Participants agreed that the ASR tool helped them distinguish Arabic sounds more accurately and revealed pronunciation errors they had not previously recognized.(Mena et al., 2026, Sun, 2023).

An explanation of the ASR process in evaluating Arabic speech among readers can be seen in the following image (Liu et al., 2025):

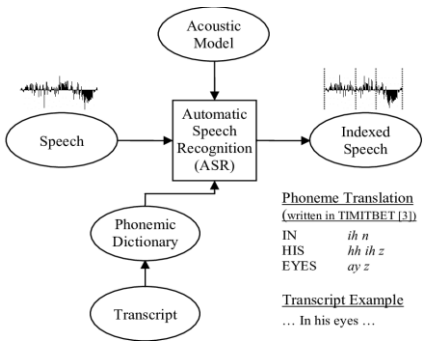

Figure 1. ASR Technology

The process is as follows:

1. Speech

Refers to the voice input produced by humans, either pre-recorded or captured live through a microphone.

2. Automatic Speech Recognition (ASR)

The core component that receives the speech input and decodes it into intelligible written words.

3. Acoustic Model

A model that links the acoustic characteristics of speech signals to phonemes. It is used to understand how sounds correspond to letters or words.

4. Phonemic Dictionary

A dictionary that translates phonemes into recognizable linguistic units.

5. Transcript

The final text output generated by the system after recognizing the speech, for example:

"Hati" (heart) ← transcribed as "*anjing*" (dog)

6. Indexed Speech

Speech that has been analyzed and time-stamped, which helps synchronize text with audio or enables targeted search.

7. Phonemic Conversion (Timitbet)

Refers to the phoneme system used in the dataset, which serves as the database for training the speech recognition system (Balula et al., 2021).

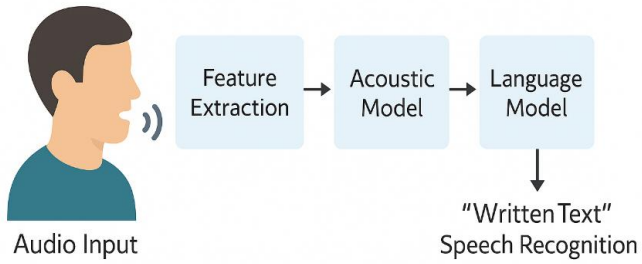

Figure 2. Evaluating Speech Using Automatic Speech Recognition Technology (Liu & Quan, 2022)

The image above illustrates the interface of ASR technology, displaying the sentence spoken by the learner/reader, followed by the transcription recognized and analyzed by the system. At the top of the screen is an audio file containing the learner's pronunciation, while the lower section presents a comparison between the expected pronunciation and the actual pronunciation. This is accompanied by an accuracy assessment using numerical or color-coded indicators, enabling precise identification of pronunciation errors (Ngo et al., 2024).

The image also illustrates how the program segments pronunciation into phonetic units, displaying the degree of alignment between the learner's articulation and the correct standard. This allows both teachers and learners to identify phonetic errors within static and dynamic clusters, such as harsh, whispered, or exaggerated sounds, as well as other distinctive features of Arabic phonology (Liu et al., 2025). This tool is considered one of the effective methods for teaching Arabic pronunciation, as it enables students to visualize their speech output and provides opportunities to improve their vocal performance through immediate feedback (Nasution et al., 2019).

The texts provided to students for evaluating their ability to pronounce Arabic sounds consisted of ten passages. The aspects observed by the researcher included accurate articulation of Arabic letters, the characteristics and manner of their pronunciation, short and long vowel movements, pauses and connections, as well as the correct use of *tanwîn* and *shaddah*.

1. Text 1: "يقول الله تعالى: "وَعِبَادُ الرَّحْمٰنِ الَّذِينَ يَمْشُونَ عَلَى الْأَرْضِ هَوْنًا، وَإِذَا خَاطَبَهُمُ الْجَاهِلُونَ قَالُوا سَلَامًا". (And the servants of the Most Merciful are those who walk upon the earth humbly, and when the ignorant address them, they respond with words of peace."). Assessment Points:
   a. Pronunciation of the throat letters 'ع (*'Ain*) and 'خ (*'Khâ*)
   b. Natural elongation (*madd 'alami*) in the words الرحمن (*Ar-Rahmân*) and يمشون (*Yamshûn*)
   c. Proper articulation of *tanwîn* in the word سلامًا (*Salâman*)
2. Text 2: العِلْمُ نُورٌ يَهْدِي النَّاسَ إِلَى الطَّرِيقِ الصَّحِيحِ، وَالْجَهْلُ ظَلَامٌ يُؤَدِّي إِلَى الضَّيَاعِ وَالضَّلَالِ. (Knowledge is a light that guides people to the right path, while ignorance is a darkness that leads to confusion and misguidance). Assessment Points:
   a. Accurate pronunciation of the letters "ظ" (*Dẓhâ'*) and "ض" (*Dhâd*), which belong to the emphatic consonant group
   b. Distinction between *shaddah* and *tanwîn* in the words يُؤَدِّي (*Yu'addi*) and الطَّرِيقِ (*Ath-Tharîq*)
   c. Proper articulation of "ق" (*Qâf*) and its placement at the tip of the tongu
3. Text 3: يَجِبُ عَلَى طَالِبِ العِلْمِ أَنْ يُحَافِظَ عَلَى وَقْتِهِ، وَيَسْعَى لِطَلَبِ المَعْرِفَةِ بِجِدٍّ وَاجْتِهَادٍ. (The student must safeguard their time and strive to pursue knowledge with diligence and perseverance.). Assessment Points:
   a. Observation of pause and connection movements in the words يجب (*yajibu*) and يحافظ (*yuhâfiẓu*)
   b. Accurate pronunciation of the letters "ج" (*Jîm*) and "ق" (*Qâf*)
   c. Attention to stop signs and connections in the word واجتهاد (*wajtihâd*)
4. Text 4: الطَّقْسُ فِي هَذِهِ الأَيَّامِ مُتَقَلِّبٌ، فَقَدْ تَتَغَيَّرُ الأَحْوَالُ مِنْ شَمْسٍ إِلَى مَطَرٍ فِي سَاعَةٍ وَاحِدَةٍ. (The weather in recent days has been unpredictable, as conditions can shift from sunshine to rain within a single hour). Assessment Points:
   a. Pronunciation of the letters "ط" (*Thâ'*), "ق" (*Qâf*), and "غ" (*Ghayn*) with appropriate high and low pitch articulation

b. Differentiation between high-pitched sounds in مُتَقَلِّبٌ (*mutaqallibun*) and تَتَغَيَّرُ (*tataghayyaru*)
c. Accurate pronunciation of harakat: *dhammah* and *kasrah* with correct vowel marking

5. Text 5: الطُّلَّابُ يَزُورُونَ المَكْتَبَةَ الجَامِعِيَّةَ لِقِرَاءَةِ الكُتُبِ وَالبُحُوثِ، وَقَدْ اسْتَفَادُوا كَثِيرًا مِنْ هَذِهِ الزِّيَارَةِ. (The students visited the university library to read books and research papers, and they gained many benefits from this visit). Assessment Points:
   a. Pronunciation of sun and moon letters (*lâm shamsiyah* and *lâm qamariyah*) in words such as الطُّلَّابُ (*ath-thullâb*) and الكُتُبِ (*al-kutub*)
   b. Proper articulation of *tanwîn* and emphasis in words like زَارَ (*zâra*) and اسْتَفَادُوا (*istafâdû*).
   c. Accurate pronunciation of the letters ز (*Zay*), س (*Sîn*), and ث (*Thâ'*) in the final words.

The Implementation of ASR among Arabic Language Education Students at UIN Sumatera Utara

The experiment was conducted as illustrated in the following root-based analysis:

Table 1. Visual representation of students' ability to pronounce Arabic letters using automatic speech recognition technique

No	Student	*Tanwîn* and Syaddah	*Waqf* (Pause) and *Washl* (Continuation)	Short and Long Vowels (*Harakat*)	Letter Characteristics and Articulation Points (*Makhârij*)	Correct Letter Pronunciation
1.	Student - 1	Correct	Correct	Correct	Incorrect	Correct
2.	Student – 2	Correct	Correct	Correct	Incorrect	Correct
3.	Student – 3	Correct	Correct	Correct	Incorrect	Incorrect
4.	Student – 4	Correct	Correct	Correct	Correct	Correct
5.	Student - 5	Correct	Correct	Correct	Correct	Incorrect
6.	Student – 6	Correct	Correct	Incorrect	Correct	Incorrect
7.	Student - 7	Correct	Incorrect	Correct	Incorrect	Correct
8.	Student – 8	Correct	Correct	Correct	Correct	Incorrect
9.	Student – 9	Correct	Correct	Incorrect	Correct	Correct
10.	Student – 10	Correct	Correct	Correct	Correct	Incorrect

After analyzing the pronunciation data of ten students using ASR technology, a noticeable variation was observed in the quality of pronunciation across five phonetic aspects: correct articulation of letters, letter characteristics and articulation manner, short and long vowel movements, pauses and connections, and the use of *tanwîn* and *shaddah*.

First – Correct Letter Pronunciation

The results showed that five students (50%) made errors in this area, indicating that certain letters were either mispronounced or substituted with others. Such errors are common among non-native Arabic speakers and require targeted auditory training and precise motor stimulation. Phonetic studies emphasize the importance of mastering letter articulation before addressing phonetic characteristics in order to achieve accurate pronunciation.

Second – Letter Characteristics and Pronunciation

Only three students (30%) demonstrated difficulty in this aspect, particularly in distinguishing letters with similar articulations, such as ‘س’ and ‘ص’, or ‘ذ’ and ‘ز’. This indicates a partial awareness of pronunciation, yet phonetic features such as elevation and articulation were not properly regulated. These challenges may stem from insufficient intensive phonetic training or limited exposure to accurate pronunciation models.

Third – Short and Long Vowel Movements

It was found that the majority of students (8 out of 10), or 80%, demonstrated strong mastery of this aspect. This reflects a solid awareness in distinguishing between short vowels and elongated sounds, which is a positive indicator of their grasp of linguistic rhythm. Moreover, this type of error is easily detected by ASR technology due to its sensitivity to sound duration.

Fourth – Pausing (*Waqf*) and Connecting (*Washl*)

Only one error was recorded in this aspect, indicating a strong understanding of reading etiquette or natural reading flow in Arabic. These results suggest that training students in expressive or ideal reading practices can effectively enhance this phonetic skill.

Fifth – *Tanwîn* and *Shaddah*

All students except one demonstrated strong mastery in this aspect. ASR technology is particularly effective in detecting missed emphasis and intonation during reading, especially since these markers are not visually prominent and can only be accurately identified through precise pronunciation.

These findings indicate that ASR technology is an effective tool for monitoring pronunciation errors in real time and with precision (Al-Āsyahriy, 2025), as it allows students to listen to their own speech and compare it directly with correct models (Ansârî & Al-Sulaimân, 2023). Moreover, the application facilitates teachers in identifying individual errors and providing immediate feedback (Moneus & Sahari, 2024). This technique is recommended for use in pronunciation training programs for Arabic language learners (Al-Aḥmarî, 2025), due to its positive impact on enhancing phonological awareness and pronunciation quality (Al-‘Aẓamî, 2025). This is further supported by Western studies such as Li & Fung (2021) in Maglogiannis et al., (2021), which demonstrate the influence of ASR in improving pronunciation skills among second language learners.

These results reinforce the findings of Xiao & Park, which indicate that ASR technology is capable of diagnosing pronunciation errors with a high degree of alignment to human assessment, particularly at the partial or syllabic level. Furthermore, the study by Maglogiannis et al. (2021) demonstrates that integrating technology into phonetic instruction enhances learners' ability to recognize their own errors and improve their linguistic performance independently. Based on these findings, ASR technology in Arabic phonetic instruction presents a promising approach for improving pronunciation teaching and correcting errors in a scientific and effective manner, especially within Arabic language learning environments for non-native speakers.

Beyond these empirical findings, the study highlights a broader pedagogical implication concerning the role of digital phonetic assessment in Arabic education. The ASR-based feedback system not only functions as an evaluative mechanism but also as a metacognitive scaffold that encourages learners to monitor their own pronunciation process. This aligns with Vygotskian principles of self-regulated learning, wherein students actively participate in the correction of their linguistic performance. As observed during feedback sessions, students demonstrated increased self-awareness in articulating complex phonemes such as 'Ain (ع), Dhâd (ض), and Qâf (ق). They reported a sense of autonomy in revising their pronunciation patterns even outside formal classroom sessions, which indicates the sustainability of ASR-driven learning (Dou & Ziane, 2024).

Moreover, the integration of ASR in Arabic phonetics teaching represents a shift from teacher-centered evaluation to data-driven formative assessment. The program's instant diagnostic capability provides teachers with quantifiable evidence of students' phonetic development, allowing them to adapt their instruction more precisely. Such digital trace data, including time-stamped phoneme errors and accuracy rates, facilitate longitudinal tracking of student progress. This mirrors the pedagogical trend toward learning analytics, which emphasizes personalized and adaptive learning environments (Aldarmaki & Ghannam, 2023).

In terms of student perception, qualitative feedback indicated that learners perceived ASR technology as an engaging and motivating tool. The immediate visual display of their phonetic performance—through waveforms, color codes, and accuracy percentages—stimulated their intrinsic motivation to improve. The gamified aspect of self-correction and measurable progress created a sense of achievement that traditional pronunciation drills often fail to provide. This confirms findings by Sun (2023), who reported that integrating interactive feedback tools enhances learner persistence and reduces pronunciation anxiety among Arabic and EFL learners.

Furthermore, from a linguistic standpoint, ASR technology promotes phonological consciousness—the ability to perceive, segment, and manipulate sounds within words—which is a fundamental skill in mastering Arabic phonetics. Students who initially struggled with subtle contrasts such as /s/ vs. /sh/ or /h/ vs. /ḥ/ gradually demonstrated improved accuracy after repeated ASR-based exercises. This development is consistent with Flege's Speech Learning Model (SLM), which suggests that repeated auditory exposure coupled with articulatory feedback accelerates the restructuring of phonetic categories in second language acquisition. A recent study by

Aldarmaki & Ghannam (2023) further supports this by demonstrating that ASR systems are increasingly capable of recognizing diacritic-based distinctions in Arabic, thereby improving their diagnostic reliability for Arabic phonetic training.

Another significant aspect concerns teacher professional development. Teachers reported that ASR-based tools equipped them with an objective reference point when assessing student pronunciation, minimizing subjectivity that often accompanies auditory evaluation. It also helped bridge the gap between linguistic theory and classroom practice by providing empirical visualization of articulation errors. In this way, ASR serves as both a diagnostic and didactic instrument, fostering a research-based approach to phonetic pedagogy in Arabic education. These findings are aligned with the work of Maglogiannis et al. (2021), who emphasize that ASR-based feedback improves teaching consistency and provides teachers with concrete pronunciation evidence for evaluation.

Finally, the study underscores that technology integration must be contextually grounded. While ASR provides substantial advantages, its successful implementation depends on technical literacy, stable internet access, and appropriate teacher training. Hence, institutions should adopt a hybrid approach that combines ASR with traditional phonetic instruction. Blended learning models—where ASR supplements, rather than replaces, teacher-guided articulation practice—appear to yield optimal outcomes. This integrative framework supports not only the development of pronunciation accuracy but also enhances digital competence, preparing students for future technology-mediated learning environments (Ahlawat et al., 2025; Bin Subait et al., 2025; Ngo et al., 2024; Wilschut et al., 2024; Xiao & Park, 2021).

ASR technology represents a transformative innovation in Arabic phonetic education. It bridges the gap between theory and practice, supports personalized pronunciation training, and empowers both teachers and learners to engage in evidence-based improvement. Future research should expand the sample size and include comparative studies across institutions to evaluate cross-contextual applicability. Moreover, longitudinal analysis can further explore the extent to which ASR-based pronunciation training contributes to sustained phonological improvement and communicative competence in Arabic.

Conclusion

Following the implementation of ASR technology to evaluate the performance of ten students in Arabic phonetics, it is evident that this technology serves as an effective educational tool. It contributes to the accurate and immediate diagnosis of pronunciation errors, particularly in phonetic aspects that are difficult to detect through traditional assessment methods. The analysis of phonetic performance revealed variation among students across five pronunciation dimensions; however, the majority demonstrated significant improvement in articulating movements, pauses, and intonation. Some challenges remained in the pronunciation and phonetic characteristics of certain letters, which can be addressed through regular training and the use of automated analysis tools.

The use of ASR provides learners with opportunities for self-review and direct correction through visual and auditory feedback, enhancing their phonetic awareness and encouraging gradual, targeted improvement in pronunciation. It also enables teachers to monitor each student individually and diagnose weaknesses in a scientifically grounded manner.

Although this study provides a clear overview of the use of ASR technology in teaching Arabic phonetics to students, it has several limitations that should be considered. First, the sample was limited to a small number of students within a specific university setting, which restricts the generalizability of the findings to broader populations. Only one ASR program was used, which does not reflect the diversity of available software or its performance across different educational environments. The study also did not address individual differences in local dialects or linguistic backgrounds, which may influence learners' pronunciation outcomes. Furthermore, the research focused solely on phonetic skills without analyzing the impact on other vocal competencies such as intonation and rhythm.

Based on these limitations, several opportunities for future research can be identified to deepen understanding and expand the benefits of ASR technology in Arabic language instruction. These include broadening the scope of research to involve diverse student populations from multiple universities, thereby ensuring a more accurate representation of learners. Comparative studies between various ASR applications and testing their effectiveness across different learning environments, virtual, physical, and hybrid, are also recommended. Additionally, research into the psychological and emotional impact of ASR use during the learning process, as well as the extent to which this technology motivates students to improve their pronunciation, would offer valuable insights.

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