

Acoustic Analysis and Phonological Interference of the Phoneme /h/ in Arabic Speech Among Universitas Pendidikan Indonesia Students

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Abstract: This study aims to identify the forms of phonological interference occurring in the pronunciation of the phoneme /h/ and to analyze its acoustic characteristics in the Arabic speech of students at Universitas Pendidikan Indonesia. The phoneme /h/ is a voiceless pharyngeal fricative consonant that has no direct equivalent in Indonesian. The differences between the Arabic and Indonesian phonological systems may lead to phonological interference in the production of this phoneme by learners of Arabic. Difficulties in articulating /h/ often result in sound substitution, weakened articulation, or modifications of phonetic characteristics that affect pronunciation accuracy. This study employed a qualitative approach using a descriptive-analytical method. The data consisted of recorded speech samples containing the phoneme /h/. Data were collected through recorded pronunciation tests and subsequently analyzed using Praat software to examine acoustic parameters, including duration, intensity, and spectrogram patterns. Phonological analysis was conducted to identify pronunciation deviations resulting from the influence of the speakers' first language. The findings reveal that some students experienced phonological interference in producing the phoneme /h/, primarily through the substitution of /h/ with /h/ and the reduction of its characteristic pharyngeal frication. Acoustic analysis demonstrated differences in energy distribution and frication intensity between the students' productions and the standard Arabic pronunciation. These findings indicate that the influence of the mother tongue continues to play a significant role in the production of Arabic phonemes. The study highlights the importance of an acoustic phonetic approach in developing more effective Arabic pronunciation teaching strategies.

Keywords: Acoustic Phonetics; Arabic Language; /h/ Phoneme; Phonological Interference.

Introduction

Understanding phonological interference plays a crucial role in supporting cross-cultural communication because it can enhance language competence, particularly in listening, speaking, and language proficiency assessment. Furthermore, Arabic holds a strategic position in various domains, such as education, business, culture, international relations, and religion. In Indonesia, many Muslims from various regional language backgrounds, such as Sundanese, Javanese, and Batak, study Arabic as a means to understand the Quran. However, Arabic language proficiency among Muslims is still relatively limited, so most still rely on translations to understand the Quran's content. Therefore, translating the Quran is a crucial need and is seen as a necessary effort for Muslims who have not yet mastered Arabic (Al Farisi, 2018).

In oral communication, speakers do not simply pronounce the desired word, but first go through a process of lexical selection, a cognitive process of selecting vocabulary that best suits the intended meaning of their utterance. This process involves activating the mental lexicon, a collection of knowledge about words stored in memory, encompassing their meaning, phonological form, grammatical categories, and usage in specific contexts. While speaking, several candidate words can be activated simultaneously, requiring speakers to select the most appropriate lexical representation while simultaneously distinguishing between words with phonetic similarities. This ability is crucial in second language learning, including Arabic, which has a number of phonemes not found in Indonesian or regional languages, such as Sundanese. If the phonological representation of these phonemes is not optimally formed, speakers tend to replace them with the closest sounds in their first language. As a result, the lexical selection process does not produce accurate pronunciation, resulting in phonological interference that can alter word meaning and reduce communication effectiveness (Hameu et al., 2021).

Accuracy of Arabic pronunciation is a primary prerequisite in learning Arabic, especially to ensure that the meaning is conveyed accurately in the recitation of the holy text of the Qur'an (Nurholis et al., 2026). This linguistic accuracy is crucial because small deviations at the phonetic level can hinder the delivery of the original meaning of the source text, even potentially causing semantic shifts that affect the quality of worship and understanding. Therefore, mastery of the science of phonetics ('ilm al-aṣwāt) is the main foundation for ensuring that each phoneme is pronounced according to the correct rules of articulation (Lara et al., 2024).

However, in practice, second language learners often experience phonological interference, a phenomenon in which the phonological system of the mother tongue (L1) influences the way learners pronounce phonemes in the second language (L2) (Farisi et al., 2025). This articulation challenge generally occurs in hijaiyah letters that do not have equivalents in the phonological system of the speaker's local language, such as Sundanese, Javanese, or Batak. The phoneme /h/ (ح) is included in the group of guttural or pharyngeal consonants that have high

articulation complexity because it involves a secondary articulation mechanism not found in Indonesian. This often causes learners to make sound substitutions, such as replacing the phoneme with a sound that is closer in their language system, which can be acoustically detected through changes in sound energy patterns (Annisa et al., 2024).

To scientifically identify these articulation deviations, an objective evaluation method through acoustic phonetic analysis is required. Using software such as Praat allows researchers to precisely map sound characteristics using parameters such as duration, fundamental frequency (pit), intensity, and formant patterns (F1 and F2). Formant analysis is particularly effective for observing the phenomenon of velarization, or narrowing of the point of articulation, which indicates the stability of sound production. Through this approach, sound distortions due to L1 interference can be quantitatively measured, providing a more complete picture than purely subjective assessments.

Previous studies have explored phonological interference on other phonemes such as /f/ and /dʒ/ among university students and non-native speakers in Indonesia (Ali et al., 2023; Nurholis et al., 2026). However, an in-depth analysis focusing specifically on the acoustic characteristics and phonological interference of the phoneme /h/ in students at the Universitas Pendidikan Indonesia (UPI) still requires further study to map specific articulation barriers in academic contexts. This study aims to analyze the speech of UPI students acoustically to identify interference patterns that occur, so that the results can be an important contribution to the development of more effective and applicable Arabic language learning strategies.

Method

This study used a qualitative approach with a descriptive-analytical method to describe the form of phonological interference in the pronunciation of the Arabic phoneme /h/ (ح) by students. This approach was chosen because it allowed the researcher to obtain an in-depth picture of the characteristics of the participants' pronunciation based on phonological and acoustic phonetic analysis. The study was conducted at the Arabic Language Education Study Program, Universitas Pendidikan Indonesia.

Research participants were selected using a purposive sampling technique, namely a technique for determining samples based on certain considerations in accordance with the research objectives (Raharjo, 2017). The research data is in the form of speech samples containing the phoneme /h/. Data collection was carried out through a pronunciation test using a vocabulary list that had been compiled based on the distribution of the phonemes. All utterances were recorded using digital recording devices under controlled conditions to obtain adequate audio quality for acoustic analysis. The recordings were then transcribed according to the participant's identity and the position of the analyzed phonemes.

Data analysis was conducted using acoustic phonetic analysis using Praat software to measure the acoustic characteristics of the pronunciation of the phoneme /h/, including duration, intensity, and spectrogram patterns. This analysis aims to identify the characteristics of sound production objectively based on visual representation and acoustic parameters. Furthermore, phonological analysis was conducted to identify forms of phonological interference that arise as a result of the influence of the first language. The results of this analysis were then interpreted descriptively to explain the patterns of phonological interference and the characteristics of pronunciation errors experienced by the participants.

Results and Discussion

The phoneme /h/ is a voiceless pharyngeal fricative that is characteristic of the Arabic phonological system. This phoneme is produced through narrowing of the pharyngeal wall without involving the vibration of the vocal cords, thus producing a distinctive frication (Watson, 2002; Ladefoged & Johnson, 2015). Unlike the phoneme /h/, which is articulated at the glottis, the phoneme /h/ requires a stronger contraction of the pharyngeal muscles and is therefore articulatory more complex.

Indonesian does not have a pharyngeal phoneme in its phonological inventory. As a result, Arabic learners often experience difficulty in producing the phoneme /h/ correctly. This difficulty usually manifests itself in the form of substitution of the phoneme /h/ for /h/ or another sound deemed closest based on the phonological system of the mother tongue. These errors not only indicate phonological interference but also have the potential to change lexical meaning in Arabic because the difference in a single phoneme can differentiate word meanings (at least in pairs) (Watson, 2002).

The development of experimental phonetics allows for more objective pronunciation analysis through an acoustic approach. Acoustic analysis examines the physical characteristics of speech sounds based on measurable parameters, such as duration, fundamental frequency, intensity, formants, and spectrogram patterns (Ladefoged & Johnson, 2015). This approach provides empirical evidence regarding the characteristics of sound production that cannot always be observed through auditory perception alone.

Acoustically, pharyngeal phonemes have different characteristics from other fricative consonants. The narrowing of the pharyngeal cavity produces a characteristic spectral energy distribution as well as a relatively

weak fricative pattern compared to velar or alveolar fricatives. Zawaydeh's (1999) research shows that Arabic pharyngeal consonants have spectrogram characteristics that can be differentiated through frequency energy distribution and frication duration. Therefore, spectrogram analysis is an important approach to identify whether a sound is actually produced as the phoneme /h/ or undergoes substitution into another phoneme.

In the context of learning Arabic as a foreign language, acoustic analysis serves not only as an evaluation tool but also as a means to understand the mechanisms of phonological interference. Differences in duration, intensity, and spectrogram patterns between learner and native speaker pronunciation can indicate the extent to which the phonological system of the first language influences the sound production of the second language. This approach provides a more objective basis than auditory assessment, thereby increasing the reliability of phonetic research.

Table 1 phoneme /h/ in the word (حَسَدَ)

Speaker	F0	F1	F2	Duration
Student 1	283	1087	2024	0.392361
Student 2	239	926	1926	0.256823
Student 3	227	955	1961	0.406295
Student 4	135	716	1890	0.319969
Student 5	107	780	1936	0.460546

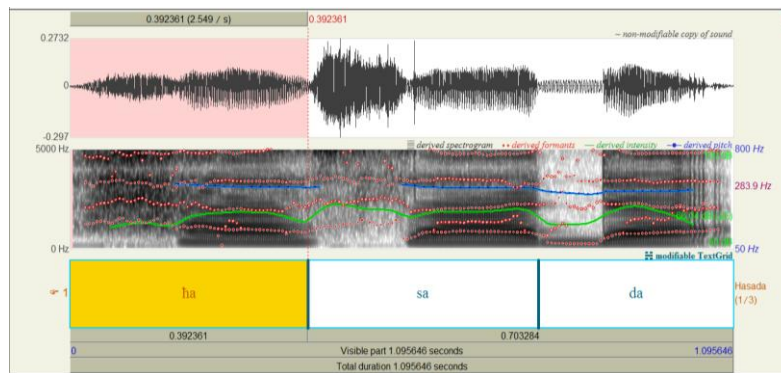


Figure 1. Spectrogram Visualization of Student 1

Based on the spectrogram visualization, the production of the phoneme /h/ at the beginning of a word indicates that the sound wave begins with a silent interval. This silent interval is not followed by a burst or vertical transition, which would indicate a stop consonant. Instead, after this interval, the spectrogram shows the emergence of fricative energy in the form of a relatively dense, continuous, and stable air hiss pattern. This flow of fricative energy continues continuously until it gradually transitions to the following vowel wave.

These acoustic characteristics correspond to the articulatory properties of the phoneme /h/ in the Arabic phonological system. The phoneme /h/ is a letter that emerges from the wasath al-halq (middle part of the throat), namely through a narrowing in the pharyngeal area that produces airflow without total obstruction. The absence of a burst pattern in the spectrogram and the presence of continuous fricative energy indicate a relationship with the nature of hams, namely the clear release of breath flow without vibration of the vocal cords, and the nature of rikhwah, namely the continuity of sound flow due to the absence of complete closure of the articulation tract. In modern phonetic studies, /h/ is categorized as a voiceless pharyngeal fricative, namely a fricative sound produced by blowing air in the pharyngeal cavity with distinctive fricative energy characteristics (Anam, 2025).

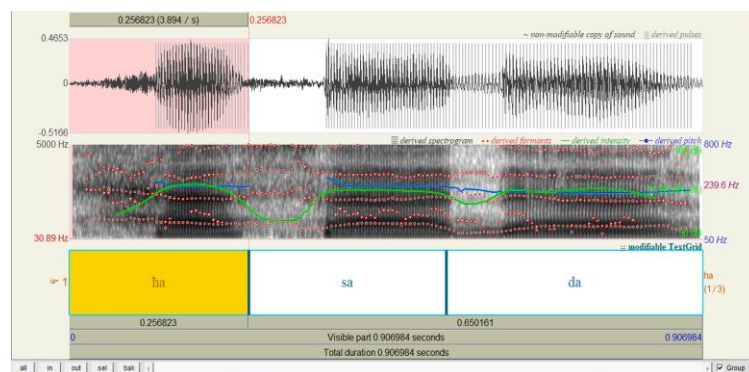


Figure 2. Spectrogram Visualization of Student 2

The production of the phoneme /h/ shows phonetic characteristics that align with the concepts of makhārij al-ḥurūf and ṣifāt al-ḥurūf in Arabic phonology studies. The results of the spectrogram visualization show the distribution of fricative energy produced by the air flow when passing through the narrowing in the pharyngeal area. Phonetically, the phoneme /h/ is a voiceless pharyngeal fricative consonant produced from wasaʿ al-ḥalq. This sound has the characteristics of hams, rikhāwah, istifāl, and infitāḥ, so that the articulation process is characterized by continuous air release without involving vocal cord vibration (Marlina, 2019).

The results of acoustic parameter measurements show a fundamental frequency (F0) value of 239 Hz, indicating the influence of the transition to the next vowel after the phoneme /h/. The first frequency value (F1) of 926 Hz reflects the configuration of the vocal cavity with a relatively wide opening and a relatively low tongue position. Meanwhile, the second frequency value (F2) of 1926 Hz indicates the influence of the resonance of the front of the oral cavity due to the presence of the vowel fathāḥ following the phoneme. The sound duration of 0.256823 seconds shows that the frication phase lasts quite long, so that the characteristics of air friction on the phoneme /h/ remain clearly audible in speech production (Marlina, 2019; Al Farisi et al., 2025).

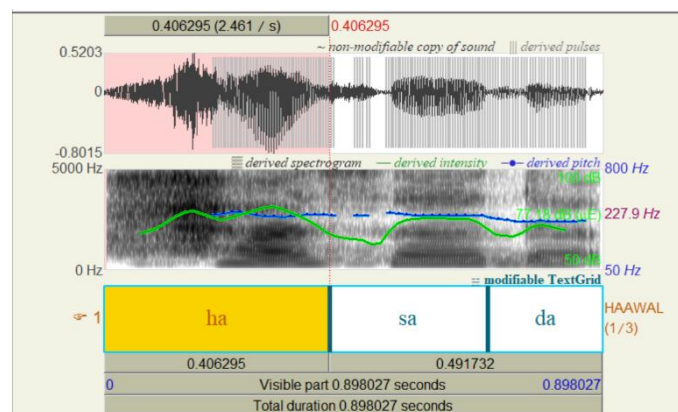


Figure 3. Spectrogram Visualization of Student 3

Based on the results of acoustic analysis using Praat software, the production of the phoneme /h/ in the initial position of the word shows phonetic characteristics that are close to the articulation pattern of standard Arabic. The fundamental frequency parameter (F0) was recorded at 227 Hz, which is the highest value compared to the realization of the phoneme /h/ in other positions. The high F0 value at the beginning of the utterance indicates a greater activation of articulatory energy when the speaker begins sound production.

In terms of resonance, the Formant 1 (F1) value of 955 Hz indicates a relatively large vocal cavity opening with a more open jaw position when the sound is released towards the next vowel. Meanwhile, the Formant 2 (F2) value of 1961 Hz describes the resonance characteristics that move towards the front of the oral cavity. Based on the duration parameter, the phoneme /h/ is realized for 0.406 seconds, which indicates a relatively long frication time span. This duration is in accordance with the characteristics of fricative phonemes that require continuous air flow without any total obstruction in the articulation tract. The long duration realization indicates that the characteristics of rakhāwah (continuous sound flow) and hams (exhalation of breath without vibration of the vocal cords) can be maintained by the speaker during the sound production process.

The integration of acoustic measurement results in the form of F0, F1, F2, and duration with the concepts of makhārij al-ḥurūf and ṣifāt al-ḥurūf shows that this student has quite good articulatory ability in realizing the phoneme /h/ in the initial position of the word. There was no indication of glottal substitution interference, namely the change of the phoneme /h/ to /h/, which often occurs in Arabic learners as a second language due to the influence of the phonological system of the first language. The relatively high F1 value indicates adequate opening of the vocal cavity, while the stability of F2 reflects the success of the speaker in maintaining the resonance character of the pharyngeal sound. In addition, the long duration of frication strengthens the evidence that the characteristics of rakhāwah and hams have been well realized. Thus, the production of the phoneme /h/ by the speaker shows a form of positive approximation, namely the ability to approach the pronunciation pattern of the target language although there is still the possibility of acoustic variation due to the influence of the phonological system of the first language (Kazi, 1987).

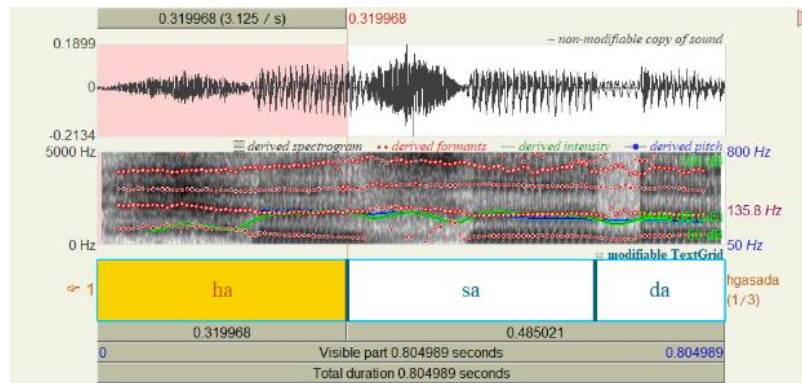


Figure 4. Spectrogram Visualization of Student 4

The results of the acoustic analysis indicate that the production of the phoneme /h/ in the initial position experiences phonological interference in the form of a substitution into the phoneme /h/. This change indicates the influence of the speaker's first language phonological system, which does not have a pharyngeal sound category like /h/. In both Indonesian and Sundanese, the sound closest to the characteristics of /h/ is the glottal phoneme /h/, so speakers tend to assimilate the target sound into the phonological category already available in their first language. This phenomenon is in line with the concept of language transfer, which explains that second language learners often use first language articulation patterns when faced with sounds that are not found in their phonological system (Lado, 1957; Flege, 1995).

Based on acoustic parameters, the sound duration of 0.31 seconds indicates that the speaker still maintains the fricative character with a relatively long air flow. However, the F1 value of 716 Hz and F2 of 1890 Hz indicate a change in resonance character due to a shift in the location of articulation from the pharyngeal region to the glottis. These values indicate that the narrowing of the pharynx which is the main characteristic of the phoneme /h/ is not realized optimally, so that the sound production is closer to the characteristics of the phoneme /h/. In addition, the F0 value of 135 Hz indicates the influence of surrounding vowels, considering that both the phonemes /h/ and /h/ do not involve vocal cord vibration.

Thus, the analysis results indicate that the speaker experiences phonological interference in the form of a pharyngeal-to-glottal substitution, namely the change of the phoneme /h/ to /h/. This interference occurs due to the speaker's limited phonological representation of Arabic pharyngeal sounds and a tendency to use sound categories available in their first language.

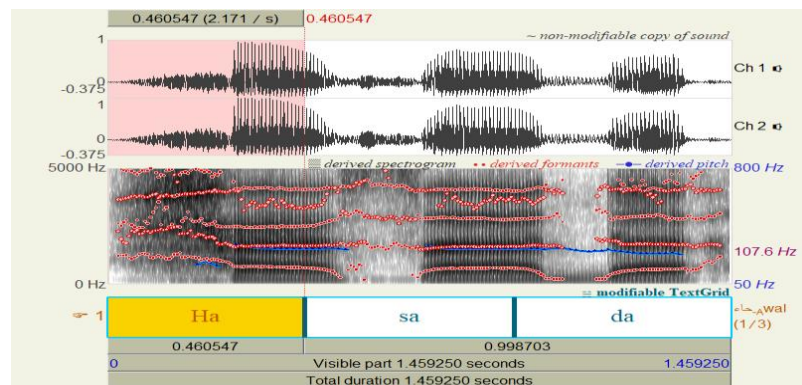


Figure 5. Spectrogram Visualization of Student 5

Based on the results of acoustic analysis using Praat software, the production of the phoneme /h/ by the speaker shows a tendency for interference in the form of substitution towards the phoneme /h/. The results of acoustic parameter measurements show a fundamental frequency (F0) value of 107 Hz, Formant 1 (F1) of 780 Hz, and Formant 2 (F2) of 1936 Hz, with a pronunciation duration reaching 0.460546 seconds. The acoustic value pattern shows that the resulting sound has characteristics that are closer to the phoneme /h/ than the target phoneme /h/. This is caused by differences in the location of articulation between the two phonemes, where /h/ is produced through narrowing in the wasaṭ al-ḥalq (pharynx) area, while /h/ is produced in the glottis area. This change in the location of articulation causes a reduction in the pharyngeal characteristics that are the main characteristics of the phoneme /h/.

In terms of resonance parameters, the F1 value of 780 Hz and F2 of 1936 Hz indicate a change in the configuration of the resonance chamber due to the weakening of the narrowing in the pharyngeal region. When the phoneme /h/ is realized as /h/, the articulation tends to shift towards the glottal so that the acoustic character

of the sound changes. Although the F0 value of 107 Hz still indicates the stability of the production of voiceless sounds and does not show significant disturbances in the phonation mechanism, the formant pattern indicates that the speaker does not fully maintain the pharyngeal articulation characteristics of the phoneme /h/. This phenomenon indicates the influence of the first language phonological system which causes the speaker to use a sound category that is closer and already available in the mother tongue, namely the phoneme /h/.

Based on the overall acoustic parameters, the production of the phoneme /h/ by the speaker can be categorized as experiencing phonological interference in the form of a substitution of the pharyngeal phoneme /h/ into the glottal phoneme /h/. The stability of the F0 value indicates that the phonation mechanism is still maintained, but changes in the formant pattern and duration indicate a shift in sound characteristics due to the influence of the first language. This finding strengthens the view that the absence of pharyngeal phonemes in the phonological system of Indonesian and the speaker's regional languages causes phonological transfer, so that sounds that do not have an equivalent in the first language tend to be realized through the sound that is closest articulatory (Nasution, 2010; Flege, 1995).

Phonological interference occurs when second language (L2) learners apply the sound system of their native language to the target language. The phoneme /h/ experiences interference because this sound does not exist in the Indonesian phonological system.

The form of interference is sound substitution. Students tend to replace the phoneme /h/ with a sound that is more familiar in their L1 system, namely: Substitution to the sound [h] (glottal fricative): Students pronounce *ha* as *ha*. Acoustically, this is seen from the shift in the point of articulation from the middle of the throat (al-halq) to the lower or base of the throat.

The emergence of phonological interference in students of the Indonesian University of Education is influenced by several factors, namely, 1) Absence of Phoneme Equivalents: The absence of phoneme equivalents /h/ in Indonesian causes students to have difficulty finding the right sound reference in their phonological memory. 2) Educational Background: Students with a general formal educational background (non-Islamic boarding school) tend to have higher levels of interference than those who have intensive experience in learning *makharijul huruf* from an early age. 3) First language Articulation Habits: The habit of speaking the mother tongue that has been deeply ingrained forms phonetic patterns and sound production methods that are difficult to change instantly when learning a second language.

The difficulty in pronouncing the phoneme /h/ not only impacts the aesthetics of pronunciation but also has the potential to cause a shift in semantic meaning. For example, the sound changes in the word *hasada* (envious) to *hasada* (brave) can alter the intended message.

To minimize this interference, articulatory phonetics-based instruction should be employed. This includes the use of audiovisual media that clearly demonstrate vocal movements and the use of voice recording applications to compare student speech with native speakers. Furthermore, focused articulation practice, which focuses on difficult phonemes, should be more thoroughly integrated into the Arabic language curriculum at the university level.

Conclusion

Based on the results of acoustic analysis and phonological interference of the phoneme /h/ in Arabic speech of students of the Universitas Pendidikan Indonesia, it can be concluded that the phoneme /h/ is one of the Arabic sounds that has complex articulatory and acoustic characteristics because it is a voiceless pharyngeal fricative consonant. The production of this phoneme involves narrowing in the *wasat al-halq* (middle throat) area with the properties of *hams* and *rikhawah*, which is acoustically indicated by continuous fricative energy, relatively long sound duration, and a spectrogram pattern without bursts. The results of the analysis using Praat software show that the acoustic parameters in the form of F0, F1, F2, and duration are able to describe the characteristics of the phoneme /h/ realization objectively. Some students are able to produce the phoneme /h/ with characteristics close to standard Arabic, characterized by the stability of the spectrogram pattern, formant values that indicate pharyngeal resonance, and frication duration that is in accordance with the characteristics of the fricative phoneme. However, some students experienced phonological interference in the form of substitution of the pharyngeal phoneme /h/ into the glottal phoneme /h/, which was indicated by changes in resonance patterns, a reduction in pharyngeal characteristics, and a tendency to produce sounds that were closer to the phonological system of the first language.

This phonological interference occurs because the phoneme /h/ is not found in the phonological inventory of Indonesian or the speakers' regional languages, so students tend to use the closest sound in the phonological system they have mastered. Factors causing interference include limited phonological representation of pharyngeal sounds, Arabic learning experience, and previously formed first language articulation habits. These findings indicate that difficulties in producing the phoneme /h/ are not only related to pronunciation aspects but also have the potential to affect the accuracy of meaning in Arabic communication. Therefore, learning Arabic phonology at the tertiary level needs to integrate articulatory phonetics and acoustic phonetics approaches through

the use of speech analysis technology such as Praat, visualization media for the vocal tract, and focused articulation practice so that students are able to build new phonological categories and reduce the influence of their first language in the production of Arabic phonemes that do not have an equivalent in Indonesian.

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