SENTRI:
Jurnal Riset Ilmiah
ejournal.nusantaraglobal.ac.id/index.php/sentri

Vol. 4, No. 11, 2025
e-ISSN: 2963-1130
pp. 3340-3353

Global Trends of Segmental Phonemes Assessment in EFL: A Systematic Literature Review

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Article History:
Received: October 29, 2025
Revised: November 28, 2025
Accepted: November 30, 2025

Keywords:
English as a Foreign Language (EFL); Global trends in EFL; Phonemes Assessment; Segmental phonemes; Systematic literature review

Abstract: *This study aims to identify and analyze global trends in segmental phonemes assessment within the context of English as a Foreign Language (EFL) through a Systematic Literature Review (SLR) guided by the PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Initial data were retrieved from the Scopus and Google Scholar databases using the Publish or Perish software, yielding a total of 534 articles with relevant keywords. The screening process followed the four main PRISMA stages resulting in 20 articles that met all inclusion criteria: a focus on segmental phonemes assessment, publication between 2019–2025, and the presence of a clear research methodology. The analysis revealed that approaches to evaluating segmental pronunciation in EFL are grounded in three key theoretical pillars: intelligibility theory, phonological awareness, and technological integration in language learning. The dominant trend observed is the adoption of advanced technologies such as Automatic Speech Recognition (ASR), Computer-Assisted Pronunciation Training (CAPT), and AI-based platforms with real-time feedback, all of which have been proven to enhance pronunciation accuracy. Additionally, the findings highlight the importance of pedagogical and technical training for instructors and the limited research on teacher evaluation and cross-cultural influences. These insights provide a foundation for developing adaptive, technology-driven, and socially responsive pronunciation assessment systems that address the needs of diverse global learners in contemporary EFL education.*

How to cite: Karimah, S. A. (2025). Global Trends of Segmental Phonemes Assessment in EFL: A Systematic Literature Review. *SENTRI: Jurnal Riset Ilmiah*, *4*(11), 3340–3353. https://doi.org/10.55681/sentri.v4i11.4873

INTRODUCTION

The teaching and assessment of pronunciation in English as a Foreign Language (EFL) have undergone significant transformations alongside the global paradigm shift in language education. One of the fundamental aspects of pronunciation is segmental pronunciation, which encompasses vowel and consonant phonemes. The assessment of segmental phonemes is not merely aimed at measuring articulatory accuracy but also at evaluating intelligibility and communicative clarity within cross-cultural contexts (Levis, 2018).

In recent years, global trends have shown a growing interest in holistic assessment approaches and the integration of technology to support pronunciation learning. Tools such as automatic speech recognition (ASR), automated pronunciation scoring, and computer-assisted pronunciation training (CAPT) have increasingly been adopted to accommodate the diverse needs of EFL learners (Randall et al., 2021); (Sun, 2022).

Furthermore, contemporary studies emphasize the integration of formative and summative assessment practices to continuously measure learners' pronunciation competence development (Derwing & Munro, 2022a).

However, systematic investigations into global trends in segmental phonemes assessment remain relatively limited. Many existing studies are localized or context-specific, resulting in a fragmented understanding of how assessment approaches evolve across different countries, educational systems, and levels of technological adoption. Given this gap, it becomes crucial to conduct a comprehensive review that synthesizes current developments in this field.

Therefore, the present study aims to identify, map, and analyze recent global trends in the assessment of segmental phonemes within EFL contexts between 2019 and 2025. Specifically, it seeks to examine the dominant research designs and methodologies, the technological tools employed to support pronunciation assessment, and the criteria and frameworks used to evaluate learners' performance. Moreover, this study intends to uncover the existing research gaps and propose potential directions for future inquiry. Through a Systematic Literature Review (SLR) approach, this paper systematically investigates relevant empirical studies to provide a synthesized understanding of how segmental pronunciation assessment has evolved globally.

Ultimately, the findings are expected to contribute both theoretically and practically to the advancement of pronunciation pedagogy. Theoretically, the study offers insights into the emerging paradigms and methodological orientations shaping pronunciation assessment research. Practically, it provides evidence-based recommendations for curriculum design, teacher training, and pronunciation assessment policy development in global EFL education (Kunova & Kralova, 2025). Mapping these global trends through a systematic review thus establishes a critical foundation for designing pronunciation assessment strategies that are relevant, adaptive, and responsive to the linguistic and technological demands of the digital and multicultural era.

LITERATURE REVIEW

Segmental Phonemes

Segmental phonemes refer to the production and articulation of individual sounds in a language, consisting of vowels and consonants as the smallest units of speech (phonemes) (Abdullah & Mahmud, 2025). Segmental phonemes play a crucial role because errors in their pronunciation can alter word meanings and affect the intelligibility of speech (Yulianti et al., 2025). The teaching and assessment of segmental pronunciation involve training learners to articulate sounds accurately, identifying phonemic contrasts that may not exist in their first language (L1), and adapting to the phonological system of the target language. Moreover, segmental phonemes are often the primary focus in pronunciation curricula, as mastery of this aspect directly and significantly improves the quality of learners' spoken production. In practice, instruction in this area is commonly associated with phonetic and phonological approaches, supported using technology such as speech analysis software and speech recognition tools to enhance accuracy and the effectiveness of pronunciation evaluation.

The phonological system of English consists of phonemes, including single vowels, diphthongs (combinations of two vowels), triphthongs (combinations of three vowels), and consonants. These sounds are produced through specific movements of the tongue and other articulators in various parts of the vocal tract. (Underhill, 2013) provides a systematic

classification of English sounds in a phonemic chart based on articulatory mechanisms, which serves as an essential pedagogical tool for teachers to understand the technical aspects of pronunciation instruction. The phonemic symbols used are like those found in standard dictionaries, and familiarity with this system is considered vital for supporting effective pronunciation learning.

Consonant sounds are produced by a complete or partial obstruction of airflow in the vocal tract. There are three primary aspects used to identify and classify consonants: (1) place of articulation, referring to where the sound is produced in the mouth; (2) manner of articulation, referring to how the sound is produced; and (3) voicing, which indicates whether the vocal cords vibrate or not (voiced or voiceless). Each English consonant, therefore, possesses unique characteristics determined by one or more of these articulatory features.

Assessment in Segmental Phonemes

Segmental phonemes assessment, which focuses on the production of individual vowel and consonant phonemes, constitutes an essential component of speaking skill evaluation in the teaching and learning of English as a Foreign Language (EFL). Within the framework of the Common European Framework of Reference for Languages (CEFR), although segmental and suprasegmental features are not explicitly distinguished, the ability to pronounce sounds clearly and consistently is a key indicator under the Overall Phonological Control scale. From level B1 and above, the descriptors begin to emphasize intelligibility and sufficiently accurate articulation, reflecting the importance of control over segmental features in oral communication.

Moreover, assessment systems such as IELTS and TOEFL incorporate parameters that can be used to evaluate segmental pronunciation. In IELTS, for example, pronunciation is assessed based on the extent to which the production of sounds (including vowels and consonants) does not impede understanding, as well as the consistency of articulation as part of the pronunciation band score. Similarly, the TOEFL iBT speaking rubric evaluates clarity and control of individual sounds, particularly when test-takers respond to integrated speaking tasks.

Furthermore, the assessment approach developed by (Derwing & Munro, 2022b) provides an important foundation for evaluating the quality of segmental pronunciation. They identify three core dimensions of pronunciation assessment: intelligibility (the extent to which speech is understood), comprehensibility (the ease with which listeners can process speech), and accentedness (the degree of deviation from native-like norms). Consequently, contemporary segmental pronunciation assessment extends beyond mere phonetic precision to include its impact on cross-cultural communicative success. This shift aligns with the latest communicative and intelligibility-based assessment trends, which prioritize effective communication over phonological perfection according to native-speaker standards.

METHODS

This study employs the Systematic Literature Review (SLR) method, following the procedural framework of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) as developed by (Page et al., 2021), to ensure traceability, transparency, and replicability in the process of data collection and literature analysis. The data sources include internationally reputable scientific databases from Scopus and Google

Scholar to guarantee comprehensive, credible, and up-to-date literature coverage. The SLR serves as the main approach to systematically search, evaluate, and interpret various studies relevant to the research questions, specific topics, or phenomena under investigation (Kitchenham & Charters, 2007); (Pizard et al., 2021). The stages of data selection are illustrated in the following PRISMA diagram:

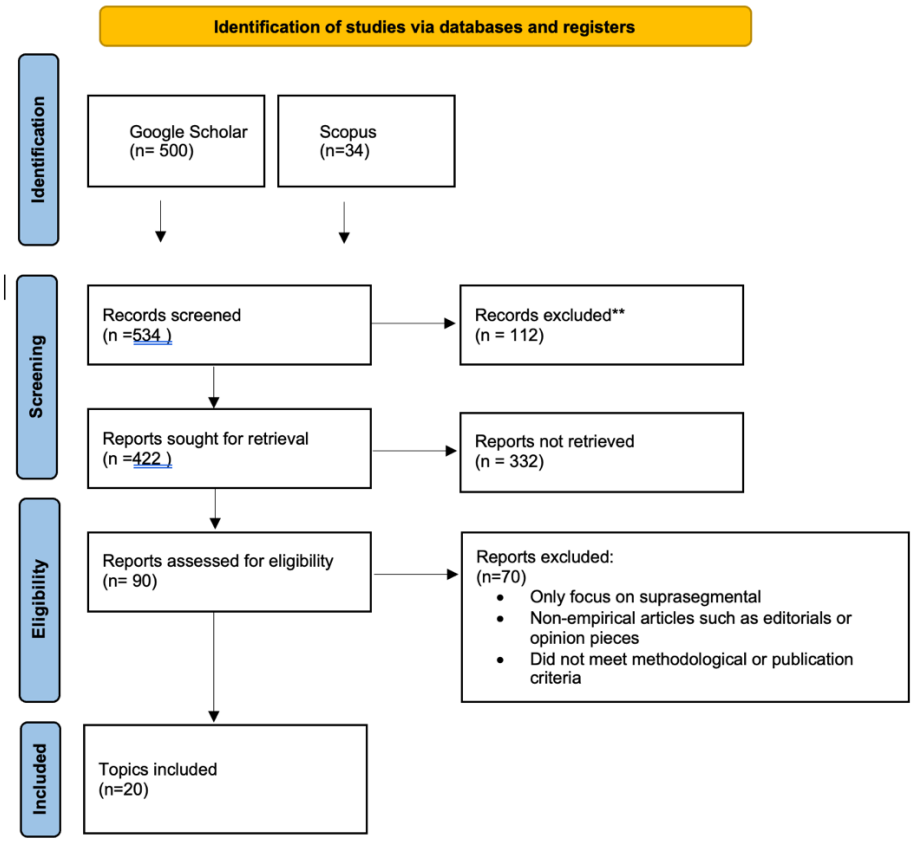

Figure 1 SLR phase based on PRISMA protocol

The process of searching and selecting articles in this study followed systematic stages based on the PRISMA 2020 protocol to ensure transparency, accountability, and replicability of the results. The literature search was conducted in June 2025 using two leading academic databases—Scopus and Google Scholar—with the assistance of the Publish or Perish software. In this process, the search engines were integrated with Scopus and Google Scholar API keys to retrieve scientifically indexed and highly reputable literature. The search procedure was systematically carried out by filtering the results based on titles, abstracts, and full texts. The initial search yielded 534 articles published between 2019 and 2025, which were then further screened and analyzed in full content according to the predefined inclusion and exclusion criteria. The inclusion and exclusion criteria are presented in Table 1 below:

Table 1 Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Type of Study	1. Empirical research (quantitative, qualitative, or mixed methods) 2. Peer-reviewed journal articles	Non-empirical works (opinions, theoretical essays, literature reviews, book chapters, dissertations,

		conference proceedings, grey literature)
Publication Language	English	Other than English
Publication Period	January 2019 – June 16, 2025	Before 2019 or after June 16, 2025
Focus Topic	1. Evaluation/assessment of segmenyal phoneme (vowels and consonants) 2. Within the EFL learning context 3. Utilizes technology when relevant	1. Focus on suprasegmental phoneme (intonation, rhythm) 2. L1 or bilingual contexts 3. Only briefly mentioning segmental assessment without implementation
Educational Context	EFL learners across various educational levels	ESL context or native English speakers (L1)

Based on the systematic selection process using rigorous inclusion and exclusion criteria, out of a total of 534 articles retrieved from the Scopus and Google Scholar databases, only 20 articles met the eligibility requirements for further analysis. These selected articles were chosen because they specifically addressed segmental phonemes assessment within the EFL context, employed empirical approaches, and were published between 2019 and 2025. This screening process ensured that only relevant, high-quality, and research-focused studies were included in this systematic review.

RESULTS AND DISCUSSIONS

The table 2 presents the 20 selected articles that met all inclusion criteria based on the PRISMA protocol. These studies represent the most relevant and recent research on segmental pronunciation assessment in EFL contexts, providing a comprehensive overview of current trends, methodologies, and theoretical frameworks in the field.

Table 2 Selected article based on PRISMA protocol

Author	Title	Year	Journal Name	Research Design & Method	Research Focus	Research Findings
Tang, J., & He, J.	Segmentals weigh much more in comprehensibility than nuclear stress in read speech	2024	Acta Psychologica	Empirical Study	Assessing segmental pronunciation in relation to comprehensibility and nuclear stress	Segmentals have a greater impact on speech comprehensibility than nuclear stress.
Nguyen, N. N., Vo, T. T., & Tran, V. D. T.	AI-Driven Pronunciation Assessment: The Impact of SpeechAce on EFL Learners' Pronunciation Competency	2025	Computer-Assisted Language Learning Electronic Journal 26(3), 84-106	mixed-method experimental design	evaluating the impact of the AI-based tool SpeechAce on improving students' pronunciation skills in English language learning	SpeechAce significantly improved students' pronunc
Saito, K.	Roles of awareness in the longitudinal development of Japanese learners' English/ɹ/pronunciation	2019	Second Language Research	Longitudinal Study	Investigating awareness and its role in English pronunciation development	Awareness plays a significant role in the development of correct /ɹ/ pronunciation in English.
Zhang, X., Miyaki, T., & Rekimoto, J.	JustSpeak: Automated, user-configurable, interactive agents for speech tutoring	2021	Proceedings of the ACM on Human	Design and Evaluation Study	Development of JustSpeak, a speech tutoring system	The system provided effective tutoring for pronunciation

						practice with real-time feedback.
Chen, HC., & Tian, JX.	Designing and Evaluating an e-Teaching Package of English Phonetics and Pronunciation for Preservice Teachers	2022	Technological Resources for Second Language Pronunciation Learning and Teaching: Research-based Approaches	Design-Based Research	Designing an e-teaching package for preservice teachers	The package effectively helped preservice teachers improve their phonetics and pronunciation teaching skills.
González, MÁ Gómez, & others.	Computer-assisted pronunciation training (CAPT): an empirical evaluation of EPSS multimedia lab	2024	Language Learning & Technology	Empirical Study	Evaluating CAPT's impact on language learning	CAPT improved pronunciation skills, especially in vowel sounds.
He, X., & Reynolds, BL.	Adaptable Teaching of Grammar, Vocabulary, and Pronunciation	2024	Springer	Conceptual Study	Investigating adaptable teaching approaches for language components	Adaptable teaching methods support better language learning, including pronunciation.
Lan, EM.	A comparative study of computer and mobile-assisted pronunciation training: The case of university students in Taiwan	2022	Education and Information Technologies	Comparative Study	Comparing computer vs. mobile-assisted pronunciation training	Both methods were effective, with mobile assistance offering more flexibility.
Fouz-González, J.	Teaching and learning pronunciation with technology: Current possibilities, pedagogical recommendations, and directions for the future	2025	Frontiers in Psychology	Review Study	Reviewing the role of technology in pronunciation instruction	Technology plays a crucial role in modern pronunciation learning, with CAPT and ASR systems being most effective.
Wang, S., Li, J., & Liang, Q.	Visual reinforcement through digital zoom technology in FL pronunciation instruction	2024	Education and Information Technologies	Empirical Study	Investigating visual reinforcement in pronunciation training	Digital zoom technology helped reinforce correct pronunciation by providing visual cues.
Zou, B., Liviero, S., Ma, Q., Zhang, W., Du, Y., Xing, P., & Du, Y.	An exploratory study of using an artificial intelligence speech evaluation system for speaking practice in EFL learning	2024	Journal of Language Teaching and Research	Exploratory Study	Exploring AI's role in EFL pronunciation evaluation	AI speech evaluation systems showed promising results in helping EFL learners improve their speaking skills.
Xiao, H., Ou, K., Wang, H., & Weijer, J van de	The Effect of ASR Apps on Monophthong Pronunciation Improvement and Generalization to New Words in English	2023	Science and Information	Empirical Study	Examining ASR apps' effect on pronunciation	ASR apps helped improve pronunciation of monophthongs and generalize to new words.
Yunita, W.	Artificial Intelligence in Academic Writing Works: EFL Teachers' and Students' Perspectives	2024	Academic	Survey Study	Investigating AI's role in teaching pronunciation and writing skills	AI tools were perceived positively by both teachers and students in improving pronunciation and writing.
Kim, J.	Primary Teachers' Knowledge Base of Pronunciation Instruction: Their Content Knowledge, Pedagogical Content	2023	English Teaching & Learning	Qualitative Study	Exploring teachers' knowledge on pronunciation instruction	Teachers' knowledge of pronunciation instruction was found to be comprehensive, though they need

	Knowledge, and Technical Pedagogical Content					more training on technical tools.
Al-Shallakh, MAI.	Artificial intelligence-based mobile learning in English language teaching (ELT) for EFL learners: Enhancing pronunciation with ELSA SPEAK in Oman	2023	Arabian Journal of Education	Empirical Study	Evaluating the use of AI tools in EFL pronunciation improvement	ELSA SPEAK enhanced pronunciation, especially in consonant sounds, for Omani learners.
García, C. Tejedor	Design and evaluation of mobile computer-assisted pronunciation training tools for second language learning	2020	Springer	Design and Evaluation Study	Evaluating mobile CAPT tools for second language learning	Mobile CAPT tools were effective in improving learners' pronunciation, especially in stress patterns.
Zambrano, AV Martínez	Kinesthetic teaching techniques for the correct pronunciation of beginning consonant blends-sp in third-grade students	2022	Journal of Language Teaching and Research	Empirical Study	Examining kinesthetic techniques in pronunciation teaching	Kinesthetic methods helped students correctly produce consonant blends more effectively.
Bashori, M., Hout, R van, Strik, H., & others.	I Can Speak: improving English pronunciation through automatic speech recognition-based language learning systems	2024	Journal of Computer Assisted Learning	Empirical Study	Evaluating automatic speech recognition in pronunciation teaching	Automatic speech recognition systems effectively helped learners improve their pronunciation accuracy.
Alzahrani, R.	Factors affecting pronunciation for adult second language learners in Tennessee	2021	TESOL Quarterly	Qualitative Study	Investigating factors affecting pronunciation in adult learners	Learners' age and previous linguistic exposure were major factors influencing pronunciation acquisition.
Jinming, DU., & Daniel, BK.	A systematic review of AI-powered chatbots in EFL speaking practice: Transforming language education	2024	Computers & Education	Systematic Review	Reviewing the use of AI chatbots for EFL speaking practice	AI-powered chatbots have shown potential in improving EFL learners' pronunciation and speaking skills.

Based on the analysis of 20 selected articles, the trends in segmental pronunciation assessment within the EFL context reveal three major tendencies. First, the use of AI-based technologies such as SpeechAce, ELSA Speak, ASR, and CAPT has emerged as a dominant approach, proven effective in improving the pronunciation of vowels, consonants, and monophthongs, as well as enhancing generalization to new vocabulary (Nguyen et al., 2025); (Xiao et al., 2023); (Bashori et al., 2024a). Second, from an instructional design perspective, the methods employed are highly diverse—ranging from experimental and longitudinal studies to technology-based designs—indicating that segmental approaches can be developed through digital media as well as kinesthetic and visual techniques, depending on learners' needs (Zambrano, 2022); (Wang et al., 2024). Third, cognitive and social factors also play a determining role, including phonological awareness, perceptions of technology, and teacher readiness to integrate technological tools (Saito, 2019); (Kim, 2023); (Yunita, 2024). Overall, this systematic literature review highlights that technological innovation, instructional variation, and individual and contextual factors are crucial elements in developing adaptive and effective segmental pronunciation assessments in the digital era.

Theoretical Foundations Underpinning Research on Segmental Phonemes Assessment

The theoretical foundation of research on segmental phonemes assessment in the context of English as a Foreign Language (EFL) rest on three main pillars: intelligibility, technology integration in language learning, and phonological awareness as a cognitive prerequisite for pronunciation acquisition. (Tang & He, 2024) empirically demonstrated that segmental sounds—namely vowels and consonants—play a more dominant role in determining speech intelligibility than suprasegmental features such as nuclear stress. This finding reinforces the assumption that phonemic accuracy is the fundamental basis for effective communication in cross-cultural interactions. Furthermore, emphasized the importance of phonological awareness, or learners' sensitivity to the form and function of sounds, as a key determinant of success in pronunciation acquisition—particularly for phonemes absent in the learners' first language, such as /ɹ/ in English for Japanese speakers. The following diagram illustrates the theoretical trend framework underlying current research on segmental pronunciation assessment in EFL contexts.

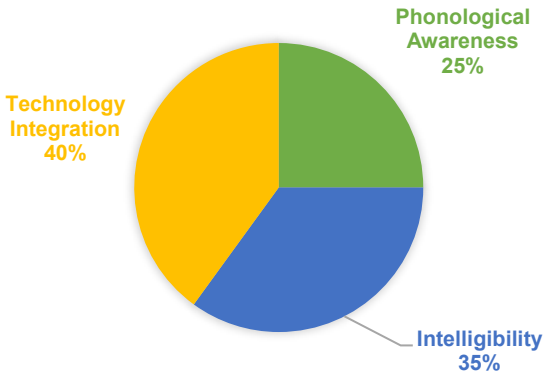

Figure 2 Theoretical Trend Framework in Segmental Phonemes Assessment

In contemporary pedagogy, the integration of technology serves as the second theoretical foundation that has gained increasing relevance. (Nguyen et al., 2025) showed that AI-based platforms such as SpeechAce can significantly enhance pronunciation competence through adaptive, instant feedback features. Similarly, (Zhang et al., 2021) demonstrated that JustSpeak, an automated and user-adaptive interaction system, accelerates pronunciation improvement. (G. M. Á. González & Lago Ferreiro, 2024) further supported these findings by evaluating Computer-Assisted Pronunciation Training (CAPT) laboratories, which were found to be particularly effective for improving vowel pronunciation—often the most challenging aspect for EFL learners.

The third theoretical pillar concerns teacher readiness and capacity. (Kim, 2023) highlighted that while teachers often possess strong pedagogical knowledge, many still require technological training to effectively integrate evaluative tools into instruction. This observation is reinforced by (Yunita, 2024), who noted that both teachers and students hold positive perceptions of AI, though practical implementation remains constrained by infrastructural and training challenges.

Taken together, intelligibility theory, technology-enhanced language learning (TELL), and phonological awareness theory form the conceptual framework underpinning the design of segmental pronunciation assessment systems that are not only evaluatively accurate but also inclusive, sustainable, and responsive to learners' needs in the digital and multicultural era.

Trends in Technology Use for Segmental Phonemes Assessment

The systematic review of 20 selected articles reveals a significant global shift toward the integration of technology in segmental phonemes assessment, particularly within the context of English as a Foreign Language (EFL) learning. The following diagram illustrates the technological trends in segmental phoneme assessment, highlighting the integration of AI, ASR, CAPT, and mobile-assisted systems as the dominant approaches shaping current and future developments in pronunciation evaluation.

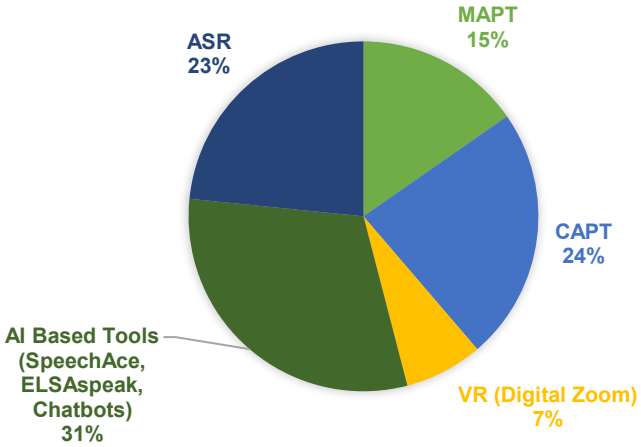

Figure 3 Global Technological Trends in Segmental Phonemes Assessments

Artificial Intelligence (AI), Automatic Speech Recognition (ASR), and Computer-Assisted Pronunciation Training (CAPT) technologies have become central elements in enhancing vowel and consonant pronunciation more efficiently, flexibly, and personally. Tools such as SpeechAce (Nguyen et al., 2025), JustSpeak (Zhang et al., 2021), and ELSA Speak (Al-Shallakh, 2023)) demonstrate not only substantial improvements in learners' pronunciation scores but also increased motivation, driven by interactive features, real-time feedback, and precise error detection. Furthermore, studies by (Xiao et al., 2023) and (Bashori et al., 2024a) highlight the role of ASR-based applications in enabling pronunciation generalization to new vocabulary, reflecting the potential of technology to facilitate linguistic skill transfer.

This trend extends beyond audio-based systems to include visual innovations such as digital zoom technology (Wang et al., 2024), which reinforces pronunciation practice through multimodal enhancement, as well as mobile evaluation systems designed for flexibility and learner autonomy (García, 2020);(Lan, 2022). Additionally, studies by (Fouz-González, 2025) and Jinming & Daniel (2024) emphasize that the integration of technology in pronunciation assessment has evolved from being merely a supplementary tool to becoming an integral component of pedagogical and instructional design.

Overall, these global trends underscore a paradigm shift in pronunciation assessment—toward approaches that are adaptive, automated, and responsive to the needs of 21st-century learners, particularly in digital, distance, and self-directed learning environments.

Variations in Research Methodological Designs and Assessment Validity

Research on segmental pronunciation assessment in English as a Foreign Language (EFL) learning demonstrates a wide variety of research designs and methodologies, reflecting the diversity of focus areas and the complexity of the issues being examined.

Most studies adopt quantitative empirical approaches to measure the impact of instructional interventions or technological tools on improving the accuracy of vowel and consonant production. Studies such as those by (Tang & He, 2024), (C. González & Hernández, 2023), and (Bashori et al., 2024b) emphasize data collection through pre-test and post-test procedures to evaluate the effectiveness of instruction and Computer-Assisted Pronunciation Training (CAPT) systems in enhancing learners' intelligibility. Meanwhile, (Nguyen et al., 2025) employ a mixed-method experimental design, combining statistical analysis with qualitative interviews to explore learners' perceptions of AI-based tools such as SpeechAce. Diagram 4 illustrates the methodological variations in segmental pronunciation assessment research.

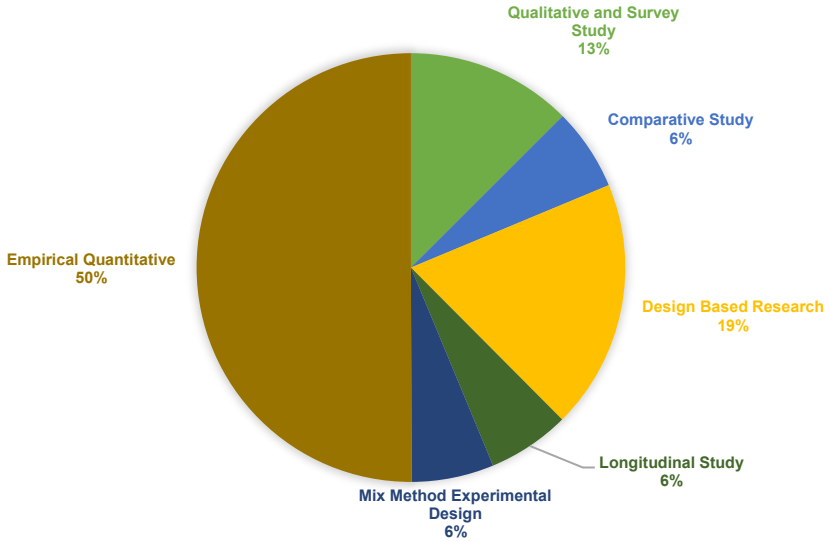

Figure 4 Methodological Design Variations in Segmental Phonemes Assessment Research

Furthermore, longitudinal research conducted by Saito (2019) provides deep insights into the long-term effects of phonological awareness on pronunciation development, particularly in the production of the /ɹ/ sound. In addition, design-based research and educational technology evaluation approaches are evident in studies such as (Zhang et al., 2021), (Chen & Tian, 2022), and (García, 2020), which not only assess the effectiveness of digital pronunciation tools but also contextualize instructional design to enhance learning outcomes. Comparative research designs, such as (Lan, 2022), investigate the relative effectiveness of computer-based versus mobile-based pronunciation training, highlighting the importance of media flexibility in pronunciation learning.

Other studies, including (Kim, 2023) and (Yunita, 2024), adopt qualitative and survey-based methods to explore the pedagogical dimensions and the readiness of teachers and students in integrating technology into pronunciation instruction. Overall, the methodologies employed in these studies reveal a growing trend toward methodological hybridity, combining quantitative and qualitative approaches to achieve a more holistic understanding. This trend reflects an evolving methodological orientation that is increasingly responsive to real-world challenges in teaching segmental pronunciation within the technologically enhanced and globalized landscape of language education.

The Role of Phonological Awareness and Intelligibility Theory in Assessment

The findings reveal that phonological awareness and the theory of intelligibility are two primary theoretical frameworks underpinning the effectiveness of segmental phonemes assessment in EFL learning. Phonological awareness—the ability to consciously identify and manipulate the sounds of language—has been shown to be a crucial cognitive factor in pronunciation development. Saito (2019) in his longitudinal study of Japanese learners of English, found that awareness of specific sound characteristics, such as the articulation of /ɹ/, can predict long-term pronunciation success. This suggests that pronunciation assessment should not only measure final outcomes but also include the ongoing process of developing phonetic awareness.

Meanwhile, intelligibility theory focuses on how comprehensible a speaker's pronunciation is to listeners in real communicative contexts. empirically demonstrated that segmental features such as vowels and consonants have a greater impact on speech intelligibility than suprasegmental features like nuclear stress. These findings highlight the importance of developing pronunciation assessments oriented toward intelligibility rather than native-like accuracy. Therefore, effective pronunciation assessment should integrate phonological awareness training with intelligibility principles as key evaluation criteria. Such an approach not only promotes articulatory accuracy but also enhances global cross-cultural communication competence.

Research Gaps and Future Directions in Segmental Phonemes Assessment

Although this systematic review highlights significant advancements in the use of technology for segmental phonemes assessment in EFL contexts, several notable research gaps remain and warrant further investigation.

First, most studies have focused primarily on the technical aspects and quantitative outcomes of technologies such as ASR, CAPT, and AI-based applications (e.g., SpeechAce, ELSA Speak), while only a few have explored learners' affective and sociocultural dimensions, such as perceptions of pronunciation accuracy in relation to linguistic identity or sociocultural pressure in classroom settings (Alzahrani, 2021; Yunita, 2024). Second, there is a limited population scope—most studies were conducted in East Asia, Southeast Asia, and the Middle East, with minimal representation from Africa, Latin America, and Eastern Europe—thus restricting the global generalizability of the findings.

Third, few studies have thoroughly integrated multimodal assessment approaches that combine auditory, visual, and kinesthetic modalities, despite emerging evidence of their potential benefits as shown in studies by Wang et al. (2024) and Zambrano (2022). Fourth, although a few longitudinal studies exist (e.g., Saito, 2019), long-term investigations on the sustained impact of technology use in segmental pronunciation learning remain scarce.

Furthermore, pedagogical research addressing teachers' competence in utilizing technology is still limited. As noted by Kim (2023), many teachers require further training in applying digital assessment tools effectively. These gaps suggest that future research should not only emphasize the technological effectiveness of pronunciation assessment but also broaden its social, psychological, and pedagogical dimensions to develop more holistic and inclusive approaches to evaluating segmental pronunciation in the digital era.

CONCLUSION

The evaluation of segmental phonemes in EFL has evolved rapidly in response to technological advancements and shifting pedagogical paradigms. Technologies such as Automatic Speech Recognition (ASR), Computer-Assisted Pronunciation Training (CAPT), and Artificial Intelligence (AI)-based applications have proven effective in improving the accuracy of vowel and consonant pronunciation, particularly through features such as real-time feedback, interactivity, and self-directed learning. Furthermore, the diversity of research designs and methodologies from empirical and longitudinal studies to exploratory investigations demonstrates a strong scholarly effort to understand the processes and effectiveness of pronunciation assessment comprehensively.

Nevertheless, several research gaps remain to be addressed, including the limited application of multimodal approaches, the geographical concentration of studies, and the insufficient attention given to affective factors and teachers' pedagogical readiness. Therefore, future directions should aim to integrate technology with cultural sensitivity, promote inclusive pedagogical approaches, and enhance professional teacher training. Such integration will help establish a model of segmental pronunciation assessment that is relevant, adaptive, and sustainable for English language learning in the 21st century.

ACKNOWLEDGEMENTS

This research was conducted independently, and no external funding or institutional support was involved. The author is solely responsible for the content and findings presented in this study.

REFERENCES

Abdullah, B., & Mahmud, L. H. (2025). Segmental English Phonemes In NF's Rap Song Story: Exploring Type And Rule. *Jurnal Onoma: Pendidikan, Bahasa, Dan Sastra*, *11*(3), 3647–3658. https://doi.org/10.30605/onoma.v11i3.6727

Al-Shallakh, M. (2023). Artificial intelligence-based mobile learning in English language teaching (ELT) for EFL learners: Enhancing pronunciation with ELSA SPEAK in Oman. *Arab Humanities Journal*, *4*(3), 208–221.

Bashori, M., van Hout, R., Strik, H., & Cucchiarini, C. (2024a). *I Can Speak* : improving English pronunciation through automatic speech recognition-based language learning systems. *Innovation in Language Learning and Teaching*, *18*(5), 443–461. https://doi.org/10.1080/17501229.2024.2315101

Bashori, M., van Hout, R., Strik, H., & Cucchiarini, C. (2024b). *I Can Speak* : improving English pronunciation through automatic speech recognition-based language learning systems. *Innovation in Language Learning and Teaching*, *18*(5), 443–461. https://doi.org/10.1080/17501229.2024.2315101

Chen, H. C., & Tian, J. X. (2022). Designing and Evaluating an e-Teaching Package of English Phonetics and Pronunciation for Preservice Teachers. *Technological Resources for Second Language Pronunciation Learning and Teaching: Research-Based Approaches*.

Derwing, T. M., & Munro, M. J. (2022a). *Pronunciation Learning and Teaching* (1st ed.). The Routledge Handbook of Second Language Acquisition and Speaking.

Derwing, T. M., & Munro, M. J. (2022b). *The Routledge Handbook of Second Language Acquisition and Speaking ; Pronunciation Learning and Teaching*.

Fouz-González, J. (2025). Teaching and learning pronunciation with technology: Current possibilities, pedagogical recommendations, and directions for the future. *Pronunciation in Second Language Learning and Teaching Proceedings*, *15*(1).

González, C., & Hernández, M. (2023). Literacy digital challenges in higher education institutions: An international perspective. *Education Sciences*.

González, G. M. Á., & Lago Ferreiro, A. (2024). Computer-Assisted Pronunciation Training (CAPT): An empirical evaluation of EPSS Multimedia Lab. *Language Learning & Technology*, *28*(1), 1–44.

Kim, J. (2023). Primary Teachers' Knowledge Base of Pronunciation Instruction: Their Content Knowledge, Pedagogical Content Knowledge, and Technical Pedagogical Content. *English Teaching & Learning*, *78*(4), 83–111. https://eric.ed.gov/?id=EJ1414678

Kitchenham, B., & Charters, S. (2007). B. Kitchenham and S. Charters, "Guidelines for performing Systematic Literature reviews in Software Engineering Version 2.3." *Engineering*, *45*(4ve).

Kunova, R., & Kralova, Z. (2025). A Systematic Review of Experimental Methods in EFL Pronunciation Enhancement: Trends, Technologies, and Gaps. *Forum for Linguistic Studies*, *7*(10).

Lan, E.-M. (2022). A comparative study of computer and mobile-assisted pronunciation training: The case of university students in Taiwan. *Education and Information Technologies*, *27*(2), 1559–1583. https://doi.org/10.1007/s10639-021-10647-4

Levis, J. M. (2018). Intelligibility, Oral Communication, and the Teaching of Pronunciation. In *Intelligibility, Oral Communication, and the Teaching of Pronunciation*. https://doi.org/10.1017/9781108241564

Nguyen, N. V., Vo, T. T., & Tran, V. D. T. (2025). AI-Driven Pronunciation Assessment: The Impact of SpeechAce on EFL Learners' Pronunciation Competency. *Computer-Assisted Language Learning Electronic Journal*, *26*(3), 84–106. https://doi.org/10.54855/callej.252635

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, n71. https://doi.org/10.1136/bmj.n71

Pizard, S., Acerenza, F., Otegui, X., Moreno, S., Vallespir, D., & Kitchenham, B. (2021). Training students in evidence-based software engineering and systematic reviews: a systematic review and empirical study. *Empirical Software Engineering*, *26*(3), 50. https://doi.org/10.1007/s10664-021-09953-9

Randall, R., Hong, Y., & Nam, H. (2021). The Effect of Real-time Score Feedback on L2 English Learners' Pronunciation and Motivation in an ASR-based CAPT System. *Korean Journal of Applied Linguistics*, *37*(4), 7–50. https://doi.org/10.17154/kjal.2021.12.37.4.7

Saito, K. (2019). Individual differences in second language speech learning in classroom settings: Roles of awareness in the longitudinal development of Japanese learners' English /ɹ/ pronunciation. *Second Language Research*, *35*(2), 149–172. https://doi.org/10.1177/0267658318768342

Sun, Y. (2022). Investigating the impact of mobile-assisted pronunciation training on EFL learners' segmental accuracy. *Computer Assisted Language Learning*, *35*(3), 212–229.

Tang, J., & He, J. (2024). Segmentals weigh much more in comprehensibility than nuclear stress in read speech. *Acta Psychologica*, *247*, 104313. https://doi.org/10.1016/j.actpsy.2024.104313

García, C. T. (2020). *Design and evaluation of mobile computer-assisted pronunciation training tools for second language learning* [Universidad de Valladolid]. https://doi.org/10.35376/10324/43663

Underhill, A. (2013). Cinderella, integration and the pronunciation turn. *IATEFL Pronunciation Special Interest Group Newsletter*, *49*.

Wang, S., Li, J., & Liang, Q. (2024). Visual reinforcement through digital zoom technology in FL pronunciation instruction. *Language Learning & Technology*, *28*(1), 1–26. https://doi.org/10.64152/10125/73558

Xiao, H., Ou, K., Wang, H., & van de Weijer, J. (2023). *The Effect of ASR Apps on Monophthong Pronunciation Improvement and Generalization to New Words in English* (pp. 1410–1433). https://doi.org/10.1007/978-3-031-37717-4_93

Yulianti, L. D., Marhum, M., & Kamaruddin, A. (2025). Pronunciation Problems of English Segmental Sounds Encountered by EFL Learners of English Education Study Program. *Jurnal Pendidikan Bahasa Inggris Undiksha*, *13*(1), 124–139. https://doi.org/10.23887/jpbi.v13i1.86838

Yunita, W. (2024). Artificial Intelligence in Academic Writing Works: EFL Teachers' and Students' Perspectives. *Academic*, 149.

Zambrano, A. V. M. (2022). Kinesthetic teaching techniques for the correct pronunciation of beginning consonant blends-sp in third-grade students. *Journal of Language Teaching and Research*. https://repositorio.puce.edu.ec/server/api/core/bitstreams/701a0bb8-4ea4-4ec6-8f28-7a39cc92acec/content

Zhang, X., Miyaki, T., & Rekimoto, J. (2021). JustSpeak: Automated, User-Configurable, Interactive Agents for Speech Tutoring. *Proceedings of the ACM on Human-Computer Interaction*, *5*(EICS), 1–24. https://doi.org/10.1145/3459744