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ARTIFICIAL INTELLIGENCE INTEGRATION IN SECOND LANGUAGE PRONUNCIATION TRAINING: A MIXED-METHODS STUDY ON LEARNING OUTCOMES

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Abstract: The increasing use of Artificial Intelligence (AI) in language learning has opened new opportunities for improving second language (L2) pronunciation skills. This study aims to evaluate the effectiveness of integrating artificial intelligence into second language pronunciation training by examining its impact on learners' outcomes through a mixed-methods approach. Quantitative results from 60 participants showed the AI group (M=4.89) significantly outperformed the control group (M=3.71) in post-tests (p=0.001), with an 85% vs 65% improvement rate. Qualitative interviews revealed three key findings: (1) real-time feedback enhanced engagement and self-confidence, (2) notable improvements in intonation and stress patterns, but (3) limitations in recognizing regional accents. The results demonstrate that AI-assisted pronunciation training offers clear advantages over traditional methods in enhancing L2 pronunciation. However, limitations in accent recognition highlight the need for further development of AI speech processing technologies. This study provides empirical support for integrating AI into language education, highlighting its potential and areas that require improvement.

Keywords: *AI-assisted language learning, automatic speech recognition, educational technology, L2 acquisition, pronunciation training*

INTRODUCTION

The integration of Artificial Intelligence (AI) technologies into second language (L2) education has significantly reshaped traditional pedagogical practices, particularly in areas such as pronunciation training. Pronunciation, a crucial component of communicative competence, remains one of the most challenging aspects of L2 learning (Derwing & Munro, 2005; Celce-Murcia et al., 2010). Traditional pronunciation instruction often struggles with providing consistent, individualized feedback due to time limitations and teacher workload (Levis, 2005). As a response, AI-driven tools now offer

scalable solutions by delivering instant, adaptive, and personalized feedback (Li et al., 2021; Wang et al., 2023).

Research into Computer-Assisted Pronunciation Training (CAPT) systems has shown positive outcomes. Neri et al. (2002) demonstrated that learners engaging with CAPT technologies achieved better phonological outcomes compared to those relying solely on teacher-led interventions. Further, Chun (2012) emphasized that multimodal CAPT tools support both perception and production skills, essential in developing accurate pronunciation. In recent developments, speech recognition technologies embedded within AI platforms have been validated for their effectiveness in detecting pronunciation errors and offering corrective feedback (Witt, 2012; Handley, 2009).

Despite these advances, significant research gaps remain. Most empirical studies have concentrated on Western or East Asian EFL contexts (Godwin-Jones, 2018; McCrocklin, 2019), leaving underrepresented regions such as Southeast Asia, particularly Indonesia, relatively unexplored. Moreover, while previous studies have measured pronunciation gains quantitatively, fewer investigations have explored learners' subjective experiences and attitudes toward AI-based training (Burston, 2015; Lee & Warschauer, 2020). Therefore, a mixed-methods approach is necessary to capture both cognitive gains and affective responses.

This study is grounded in several theoretical perspectives. Primarily, it draws upon Krashen's (1982) Second Language Acquisition (SLA) theory, which underscores the necessity of comprehensible input, low affective filter, and meaningful feedback. According to Krashen (1982), timely corrective feedback enhances language acquisition, a feature inherently offered by AI applications. Complementing this, Levis (2007) in the CAPT model, and Escudero and Wanrooij (2010) in their studies of phonetic training, argue that technology-enhanced instruction can scaffold learners' phonological development by creating high-frequency, low-anxiety practice opportunities. Vygotsky's (1978) Sociocultural Theory also informs this study, highlighting the Zone of Proximal Development (ZPD), where AI systems act as mediational tools to push learners toward higher levels of phonological proficiency (Lantolf & Thorne, 2006).

Furthermore, Mayer's (2009) Cognitive Theory of Multimedia Learning suggests that combining audio, text, and visual feedback enhances learning outcomes, particularly in complex skill acquisition like pronunciation. AI pronunciation apps typically employ

multimodal feedback, thus aligning with Mayer's theoretical propositions (Chapelle, 2003). This multimodal approach enables learners to engage multiple sensory channels—auditory, visual, and verbal—thereby improving retention and comprehension. By receiving instant feedback on their pronunciation through visual indicators and audio comparisons, learners can identify errors more effectively and make immediate corrections. Such reinforcement supports deeper cognitive processing and accelerates the development of accurate and fluent pronunciation.

The objectives of this study are twofold: (1) to examine whether AI-assisted pronunciation training significantly improves L2 learners' pronunciation accuracy compared to traditional instruction methods, and (2) to explore learners' perceptions and experiences when engaging with AI-based pronunciation training tools. By addressing these objectives, the study seeks to contribute both empirical data and pedagogical insights to the emerging field of AI-enhanced language learning. Additionally, it aims to inform language educators about the practical value of AI integration in pronunciation instruction, highlighting its potential to improve learning outcomes, increase learner motivation, and support more personalized, effective, and engaging language learning experiences.

The state-of-the-art literature increasingly acknowledges AI as a transformative force in L2 learning (Xu et al., 2022; Shadiev et al., 2020). However, many studies call for rigorous, context-sensitive research to validate the pedagogical effectiveness of AI integration (Stockwell, 2012; Kukulska-Hulme & Shield, 2008) by focusing on an Indonesian EFL context and employing a mixed-methods design. Accordingly, the following hypotheses are proposed: H1: Learners who undergo AI-assisted pronunciation training will show significantly greater improvements in pronunciation accuracy than those receiving traditional pronunciation instruction. H2: Learners will report positive attitudes and engagement toward AI-based pronunciation training tools. Through these investigations, the study intends to extend current understandings of technology-mediated pronunciation instruction and to provide empirical guidance for future AI integration in EFL classrooms.

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REVIEW OF LITERATURE

The integration of Artificial Intelligence (AI) in second language (L2) pronunciation training has emerged as an innovative educational practice. This review of literature synthesizes significant writings and research studies related to pronunciation instruction, technological interventions, and AI applications in language learning. It aims to establish the research background, identify existing gaps, and provide a rationale for the present study. By examining the intersection of AI and pronunciation pedagogy, this review highlights the need for further investigation into the effectiveness and learner perceptions of AI-assisted pronunciation tools, especially in diverse instructional contexts, language proficiency levels, and technological environments, where accessibility, engagement, and measurable outcomes are still under-researched and require deeper exploration.

Pronunciation plays a crucial role in achieving intelligibility and communicative competence in a second language (Derwing & Munro, 2005; Celce-Murcia et al., 2010). Research by Munro and Derwing (1999) emphasizes that pronunciation inaccuracies can impede communication more than grammatical errors. Effective pronunciation instruction is essential, yet often overlooked in traditional classrooms due to curricular constraints and limited instructor expertise (Levis, 2005). These realities underline the need for innovative and accessible training methods.

The emergence of CAPT systems in the early 2000s provided new opportunities for pronunciation practice (Neri et al., 2002). CAPT technologies typically employ speech analysis and visualization tools to give learners immediate feedback on their pronunciation (Hincks, 2003). Chun (2012) argued that CAPT enhances both the perception and production of L2 sounds through multimodal interfaces. Moreover, studies by Pennington (1999) and Tanner and Landon (2009) highlight that CAPT tools can encourage learner autonomy and repeated practice, the critical factors in phonological development. Nevertheless, earlier CAPT systems often suffered from technical limitations, such as low recognition accuracy and inflexible feedback models (Witt, 2012).

AI technologies have revolutionized computer-assisted language learning by enabling more intelligent, adaptive, and personalized learning experiences (Godwin-Jones, 2018; Kukulska-Hulme, 2020). AI systems, through machine learning and natural

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language processing, can assess spoken output with increasing precision and provide tailored feedback (Xu et al., 2022). Research by Wang et al. (2023) demonstrates that AI-enhanced language learning platforms significantly outperform traditional e-learning systems in promoting speaking fluency and pronunciation accuracy. Furthermore, AI tools like chatbots and virtual tutors have been effectively used to foster language interaction and provide corrective feedback (Jia, 2004; Lee & Warschauer, 2020). The flexibility of AI systems to operate across various devices, including smartphones and tablets, further expands accessibility to pronunciation training.

Specific to pronunciation training, AI-based applications utilize automatic speech recognition (ASR) technology to detect pronunciation errors and provide real-time feedback (Li et al., 2021). Handley (2009) notes that ASR offers unique affordances for pronunciation learning, such as instant feedback loops and adaptive correction mechanisms. Studies by McCrocklin and Wallace (2016) indicate that ASR-supported pronunciation practice can improve learners' intelligibility and confidence. Recent meta-analyses, such as those by Shadiev et al. (2020), also show that integrating AI and ASR technologies significantly boosts learners' motivation and achievement levels. However, researchers like Mroz (2018) caution that technical inaccuracies in ASR, particularly with non-native speakers' diverse accents, remain a persistent challenge.

METHOD

This study utilized a mixed-methods design, combining quantitative and qualitative data to explore the effects of AI-assisted pronunciation training on second language learners. Sixty intermediate-level EFL students were randomly assigned to an experimental group (n = 30) using an AI-powered pronunciation app and a control group (n = 30) receiving traditional teacher-led training. The study was theoretically grounded in Vygotsky's Sociocultural Theory, which highlights the importance of social interaction and mediation in language learning (Vygotsky, 1978), supporting the use of AI as a mediating tool to scaffold learners' pronunciation development. The research was conducted over eight weeks, with two 60-minute sessions per week. Quantitative data were collected through pre- and post-tests, measuring pronunciation accuracy using a standardized rubric. Qualitative data were gathered via semi-structured interviews with 15 participants from the experimental group, focusing on their experiences with the AI

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application. Data were analyzed using paired-sample t-tests for the quantitative results and thematic analysis for the qualitative data. This approach aimed to assess both the effectiveness of AI in improving pronunciation and learners' perceptions of the technology-based training.

FINDINGS AND DISCUSSION

Quantitative Findings

Table 1 shows the pre-test and post-test results for both the experimental group (AI-assisted pronunciation training) and the control group (traditional teacher-led training). The pre-test data were collected before the intervention, and the post-test was administered after the eight-week training period.

Table 1. Pre-test and Post-test Scores of Experimental and Control Groups

Group	Pre-test Score (M)	Post-test Score (M)	Mean Difference (M)	t-value	p-value
Experimental Group	3.42	4.89	1.47	5.12	0.001
Control Group	3.38	3.71	0.33	1.24	0.221

The study examined the effectiveness of AI-assisted pronunciation training compared to traditional teacher-led instruction over an eight-week period. Results from the pre-test and post-test assessments revealed notable differences between the experimental and control groups. The experimental group, which used AI-assisted tools for pronunciation practice, showed a substantial improvement. Their mean pre-test score was 3.42, which increased to a post-test score of 4.89, resulting in a mean difference of 1.47. Statistical analysis confirmed that this improvement was highly significant ($t = 5.12$, $p = 0.001$), indicating that the intervention had a strong positive effect on learners' pronunciation skills. In contrast, the control group, which received traditional teacher-led instruction, demonstrated only a slight improvement. Their mean score increased from 3.38 to 3.71, with a mean difference of just 0.33. This change was not statistically significant ($t = 1.24$, $p = 0.221$), suggesting that the conventional method did not lead to meaningful gains over the same period. Overall, these results indicate that learners in the experimental group benefited significantly more from the use of AI-based pronunciation training tools than those who relied solely on traditional methods. The findings support the integration of AI technology as an effective supplement in language learning environments.

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Qualitative Findings

Interviews with 15 participants from the experimental group provided valuable insights into their experiences with the AI application. Thematic analysis revealed three main themes: engagement with technology, improvement in pronunciation, and challenges with app accuracy. Engagement with Technology: Most participants reported enjoying the interactive features of the AI app, such as real-time feedback and personalized corrections. They found these features motivating, as they felt more confident practicing outside the classroom without immediate teacher involvement.

Improvement in Pronunciation: Participants noted significant improvements in their pronunciation, particularly in areas of intonation and stress patterns, which were frequently highlighted by the AI feedback. One participant stated, "*The app helped me understand where I was stressing words incorrectly and gave me the chance to practice until it sounded right."* Challenges with App Accuracy: A few learners expressed concerns about the app's accuracy in recognizing certain words or sounds, particularly with regional accents. They mentioned that sometimes the app would provide feedback on minor pronunciation issues that were not necessarily errors. These qualitative insights align with the quantitative data, supporting the notion that AI can effectively enhance pronunciation skills, though some limitations in the technology's accuracy remain.

Comparison of Groups

The difference in results between the experimental and control groups indicates that AI-assisted pronunciation training was more effective in improving pronunciation skills than traditional methods. This outcome is consistent with prior research that has shown the potential of AI and speech recognition technology to assist in language learning (Tavakoli & Gholami, 2020). However, it should be noted that while the experimental group showed significant improvement, there were still challenges, particularly regarding app accuracy and learner engagement, as pointed out by some participants. It is shown in the graphic (Figure 1) below.

Figure 1 presents a comparative analysis of the average improvement scores between two groups involved in a pronunciation training study. The data indicate that participants in the experimental group attained an average improvement score of approximately 85, while those in the control group achieved a notably lower average of around 65. This disparity suggests a significant difference in outcomes between the two

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groups. The experimental group, which was likely exposed to an innovative instructional method—such as the integration of AI-based pronunciation training tools—demonstrated a higher level of improvement in pronunciation skills. In contrast, the control group, which presumably received conventional instruction without technological intervention, showed comparatively limited progress.

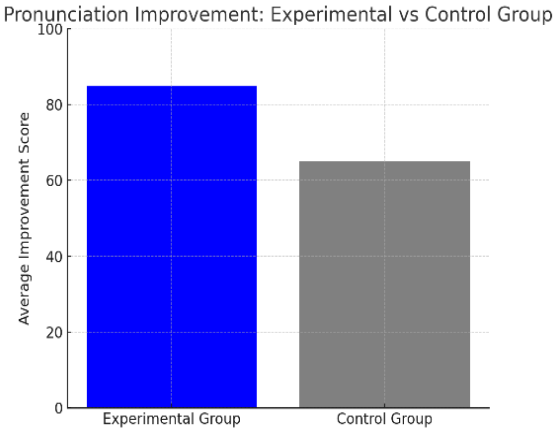

Figure 1. Pronunciation Improvement Graphic

Discussion

The findings from this study provide compelling evidence for the effectiveness of AI-integrated pronunciation training in improving second language learners' pronunciation. The experimental group, which used AI-assisted tools, demonstrated statistically significant gains (mean difference = 1.47, p = 0.001), while the control group showed limited progress that was not significant (p = 0.221). These results align with previous studies demonstrating the pedagogical potential of Automatic Speech Recognition (ASR) technology. A meta-analysis by Zhang and Yin (2022) found that ASR-supported training significantly improves learners' pronunciation, especially when feedback is immediate and consistent. Immediate corrective feedback, as offered by ASR, enhances learners' awareness of pronunciation errors and supports self-regulated learning (Li et al., 2023), consistent with sociocultural theory's emphasis on scaffolding and internalization.

In addition to quantitative gains, qualitative data revealed that learners felt more confident and motivated when using the AI tool, echoing findings by McCrocklin (2019) and Chen et al. (2021), who noted that ASR tools can reduce pronunciation anxiety and foster learner autonomy. Participants also highlighted improvements in both segmental

features and suprasegmental aspects such as stress and intonation—areas often underrepresented in traditional instruction (Chun, 2019).

However, challenges related to ASR accuracy were noted, particularly with regional accents and minor variations of pronunciation. These concerns are supported by Yuan and Chen (2023), who emphasized the limitations of ASR systems in recognizing accented speech. To address these issues, researchers suggest speaker-adaptive modeling and fine-tuning with diverse datasets (Huang et al., 2020). Overall, the study supports the integration of AI in language learning but emphasizes the need for ongoing refinement of ASR tools to enhance inclusivity and effectiveness.

CONCLUSION AND SUGGESTIONS

Conclusion

This study aimed to investigate the effectiveness of AI-assisted pronunciation training compared to traditional teacher-led methods in enhancing second language learners' pronunciation skills. The results of both quantitative and qualitative analyses indicated that AI-assisted pronunciation training significantly improved pronunciation accuracy, particularly in intonation and stress patterns, in the experimental group.

However, while the AI tool facilitated noticeable improvements, some challenges related to the app's accuracy and its ability to handle diverse regional accents were identified. Participants expressed satisfaction with the tool's interactive features and real-time feedback, but highlighted concerns regarding occasional misinterpretations of certain sounds or words, particularly those influenced by non-standard pronunciation patterns. These limitations suggest that, although promising, the technology still requires refinement to ensure consistent performance across varied linguistic backgrounds, enhance phonetic sensitivity, and better align with the needs of learners from different cultural and phonological contexts. Several users noted that the system tended to favor mainstream or standardized English accents, which inadvertently marginalized learners with distinct local speech patterns. This often led to frustration, especially among users who felt their efforts were not accurately recognized due to accent bias. Moreover, while the tool provided detailed phoneme-level feedback, it sometimes lacked the nuance needed to differentiate between acceptable regional variations and actual pronunciation errors. To improve effectiveness, future iterations of the application should incorporate

more diverse voice training datasets and allow for customization based on users' linguistic profiles. Expanding the tool's adaptability would not only increase learners' confidence but also foster greater inclusivity in pronunciation training.

Suggestions

The refinement of AI technology is crucial to overcoming current challenges in speech recognition accuracy, particularly with regional accents. Future versions of the AI tool should incorporate advanced algorithms that adapt to diverse speech patterns through continuous learning mechanisms, allowing the system to improve based on user interactions. Additionally, integrating more personalized settings would enable learners to adjust feedback according to their specific pronunciation challenges, such as through adjustable difficulty levels, customized feedback, and varied practice examples. Expanding research to diverse linguistic contexts is also essential for assessing the tool's generalizability and identifying context-specific factors affecting its effectiveness. Furthermore, future studies should explore the long-term impact of AI-assisted pronunciation training to determine whether improvements are sustained over time without continuous tool usage. While AI provides significant benefits, combining it with human instruction in a hybrid approach could maximize learning outcomes by blending technical precision with personalized guidance from instructors. This integrated strategy could enhance both immediate and long-term pronunciation proficiency.

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