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AI-Enhanced Vocabulary Acquisition in Conflict-Affected Contexts: A Study of Yemeni EFL Learners' Adaptations, Challenges, and Outcomes

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Abstract

Artificial intelligence (AI) technologies have revolutionized language learning, offering personalized, adaptive, and interactive tools for enhancing vocabulary acquisition. However, implementing AI-driven solutions in conflict-affected regions like Yemen presents unique challenges, including infrastructural constraints, socioeconomic barriers, and the need for cultural relevance. This study explores the effectiveness and obstacles of AI-enhanced vocabulary learning among 75 Yemeni university-level English as a Foreign Language (EFL) students through a mixed-methods approach. The research examines learners' engagement with AI vocabulary tools, socio-technical barriers impeding adoption, and the comparative effectiveness of AI-mediated versus traditional learning methods. The findings reveal a complex interplay between AI's potential for improving retention, engagement, and confidence, and the systemic challenges of cost, internet access, and cultural alignment. While AI tools demonstrate promise, their full impact hinges on addressing these barriers through localized solutions, policy interventions, and hybrid models that balance innovation with accessibility. This study contributes to the discourse on AI in education by highlighting the importance of contextually grounded approaches that account for the socioeconomic realities of marginalized learning environments.

Keywords: AI-mediated vocabulary learning, Conflict-affected education, Socio-technical

barriers, Technology-Enhanced Language Learning (TELL), Vocabulary Acquisition Theory, Yemeni EFL learners

1. Introduction

Artificial intelligence (AI) has revolutionized language learning through adaptive and interactive tools that enhance vocabulary and fluency development. Popular applications like ChatGPT, Duolingo, and Rosetta Stone leverage machine learning and natural language processing to deliver personalized instruction, real-time feedback, and engaging gamified exercises (De La Vall & Araya, 2023). While these technologies enable flexible, self-paced learning, issues around AI accuracy, cultural representation, data privacy, and equal access pose ongoing challenges for educational integration (Gutiérrez, 2023). Nonetheless, research demonstrates that AI-powered tools significantly improve both language mastery and cross-cultural communication abilities, making them valuable complements to conventional teaching methods (St. Fountoulakis, 2024). The technology's ability to adapt to individual needs while providing consistent practice opportunities has transformed how learners approach language acquisition, though careful consideration must be given to addressing its current limitations and ethical implications.

AI technology shows significant potential for transforming education in conflict-affected regions, offering ways to personalize learning and maintain educational continuity despite challenging conditions (Ahmed et al., 2024; Fedorenko & Chala, 2024). Through tools like adaptive learning platforms and chatbots, AI can provide individualized instruction that accommodates students' different learning speeds and circumstances in unstable environments (Adiguzel et al., 2023). The technology also helps address teacher shortages in conflict zones by automating administrative work and providing professional development resources, though success largely depends on having adequate infrastructure and resources in place (Ahmed et al., 2024). While AI solutions show promise in bridging educational gaps in these vulnerable regions, their effective implementation requires careful consideration of local contexts and available support systems.

Implementing AI-based solutions in educational settings affected by conflict is a daunting challenge fraught with practical and ethical hurdles. For teachers and students living in these turbulent environments, a lack of reliable internet, sporadic power supply, and gaps in digital skills create substantial roadblocks to effectively utilizing these new technologies (Bakhmat et al., 2024). While the promise of AI-driven tools to enhance learning through greater engagement and critical thinking is enticing, there are ongoing worries about technology overload, data privacy concerns, and ensuring equitable access for all students (Arcinas, 2024). Educators and administrators are navigating a delicate balance, trying to harness the benefits of AI-powered learning without exacerbating the existing disparities faced by vulnerable communities. These complex realities underscore the need for thoughtful, context-specific approaches that address the very human concerns of students, teachers, and families living amidst conflict, requiring empathy, flexibility, and a deep understanding of each unique educational setting.

Successful integration of AI in these challenging environments requires coordinated efforts between educators, policymakers, and community stakeholders. Ensuring that the solutions are culturally appropriate, ethically sound, and universally accessible is crucial (Bakhmat et al.,

2024). This balance between technological innovation and practical constraints highlights the need for careful consideration of local contexts when implementing AI-based educational solutions.

The transformative potential of AI in revolutionizing education in conflict-affected areas hinges on the adoption of careful implementation strategies, robust infrastructure development, and the establishment of strong ethical frameworks that prioritize inclusivity and educational effectiveness (Arcinas, 2024; Adiguzel et al., 2023). Success in this endeavor requires a delicate balance between embracing technological innovation and addressing the practical realities on the ground, ensuring that AI truly serves as a force for educational advancement in these challenging environments.

The implementation of AI-powered language learning in Yemen exemplifies both the potential and the challenges of educational technology in conflict-affected regions. While AI tools offer innovative solutions for personalized learning and educational continuity, Yemen's severe infrastructure damage and widespread disruption of schooling—with 2.4 million children unable to attend school (UNICEF, 2023)—present significant barriers to their widespread adoption (Hezam et al., 2024).

The effectiveness of AI-enhanced vocabulary tools depends heavily on addressing fundamental challenges such as limited internet access, digital literacy gaps, and the socioeconomic hardships faced by both students and teachers. Successfully integrating AI-powered learning solutions in Yemen requires careful consideration of these contextual constraints, ensuring that the tools are not only technologically advanced but also culturally appropriate, accessible, and sustainable within the region's challenging circumstances (Hezam et al., 2024).

This delicate balance between innovation and practical limitations demonstrates the need for context-sensitive approaches to bridge the digital divide while supporting English language learners in crisis-affected areas. By addressing the unique challenges of the Yemeni educational landscape, AI-powered solutions have the potential to play a transformative role in providing personalized and continuous learning opportunities, but only if they are designed and implemented with a deep understanding of the local context.

This study explores the effectiveness and challenges of AI-enhanced vocabulary learning among Yemeni university-level EFL students in a conflict-affected setting It analyzes the intersection of AI technology, vocabulary acquisition, and education in crisis contexts, seeking to inform best practices for technology-enhanced language learning in challenging environments.

The investigation focuses on student engagement with AI vocabulary tools and their most valuable features, the specific socio-technical barriers affecting AI implementation in Yemen's context, and the comparative effectiveness of AI-mediated versus traditional vocabulary learning approaches

The findings aim to provide practical insights for educators, policymakers, and technology developers working to support language education in conflict-affected regions, particularly

regarding tool adaptation, barrier mitigation, and learning effectiveness measurement This study seeks to contribute to the development of effective and contextually-appropriate technology-enhanced language learning solutions for students in conflict-affected settings, such as Yemen.

1.1 Research Questions

1) How do Yemeni EFL learners use AI tools to enhance their English vocabulary learning and acquisition?

2) What socio-technical challenges hinder the adoption of AI-driven vocabulary learning among Yemeni EFL learners?

3) How does AI-mediated vocabulary learning compare to traditional methods in improving vocabulary retention and active usage among Yemeni students?

2. Literature Review

Effective vocabulary acquisition is a cornerstone of success in English as a Foreign Language (EFL) learning, requiring strategies that foster comprehension, retention, and practical application of new words. Research underscores vocabulary growth's multifaceted nature, influenced by technological integration, task design, contextual methodologies, and learner-specific preferences (Zeng et al., 2022; Khezrlou et al., 2017). Recent advancements in artificial intelligence (AI) have introduced transformative tools capable of delivering personalized, adaptive, and interactive learning experiences, positioning AI as a promising solution to accelerate vocabulary acquisition in diverse educational contexts.

A critical determinant of vocabulary mastery lies in the linguistic characteristics of words themselves. Studies highlight that factors such as word frequency, polysemy (multiple meanings), and cognateness (similarity to the learner's native language) positively correlate with acquisition, while word length and lexicalization (fixed meanings) pose challenges (Zeng et al., 2022). To optimize learning, structured pedagogical approaches—such as explicit instruction, composition exercises, and sentence rephrasing tasks—have proven effective in enhancing vocabulary knowledge (Eskandari et al., 2024). Contextual learning further amplifies retention, with learners who generate their own contextual cues demonstrating superior comprehension compared to those relying on predefined contexts (Zhou & Wu, 2024). These insights emphasize the need for methodologies that balance linguistic complexity with active learner engagement.

Technological innovations, particularly AI-driven tools, have revolutionized vocabulary acquisition by merging interactivity with personalization. Meta-analytical research by Hao et al. (2021) demonstrates that technology-assisted learning, especially via mobile platforms, significantly enhances long-term retention over traditional methods. Applications like Duolingo and Babbel leverage adaptive algorithms to tailor content to individual proficiency levels, while tools such as Grammarly provide real-time linguistic feedback, bridging gaps in conventional classroom instruction (Agrawal, 2024; Akila et al., 2024). AI-powered chatbots and virtual tutors further extend learning beyond physical classrooms, offering flexible,

on-demand support that aligns with diverse learner needs (Siregar et al., 2024). These advancements underscore AI's potential to democratize access to high-quality language education, particularly in underserved regions.

In conflict-affected areas like Yemen, AI tools offer a lifeline for sustaining education amid instability. Research in Ukrainian tertiary education highlights AI's role in mitigating disruptions through intelligent tutoring systems and natural language processing applications, which address gaps in traditional vocabulary instruction (Nykyporets et al., 2024). Similarly, studies in Yemen revealed that EFL learners actively engage with AI tools such as ChatGPT and Grammarly, reporting improved retention and confidence despite infrastructural constraints (Hezam et al., 2024). However, the implementation of AI in these contexts is fraught with challenges, including safety concerns, psychological stressors, and systemic barriers such as unreliable internet and power shortages (Лущук & Циганок, 2024). These obstacles underscore the necessity of context-sensitive AI solutions that account for the socio-political realities of conflict zones.

Despite its promise, AI-enhanced vocabulary learning faces significant hurdles. Technical and infrastructural barriers—such as system reliability, data dependency, and high costs—limit accessibility, particularly in regions like Yemen where connectivity is sporadic (Crompton et al., 2024; Evenddy, 2024). The reduced role of human educators in AI-driven environments also raises concerns about diminished social interaction and engagement, a critical issue in conflict settings where interpersonal connections are vital for psychological resilience (De La Vall & Araya, 2023). Furthermore, many AI tools lack cultural adaptation, failing to align with Arabic-speaking learners' linguistic and curricular needs, thereby necessitating localized redesigns (Sujatna et al., 2024). Addressing these challenges demands a holistic approach that harmonizes technological innovation with socio-cultural and infrastructural realities.

Future research must prioritize longitudinal studies to assess AI's long-term impact on language proficiency and retention. Additionally, the development of culturally relevant AI models, particularly those integrating Arabic-friendly natural language processing, remains a critical frontier. Hybrid pedagogical models that synergize AI-driven tools with traditional instruction could offer a balanced framework, maximizing the benefits of both approaches in resource-constrained environments. By addressing these gaps, stakeholders can unlock AI's full potential to deliver equitable, engaging, and contextually grounded vocabulary education for EFL learners in conflict-affected regions.

This synthesis not only contextualizes AI's role in vocabulary acquisition but also highlights the urgent need for innovations that reconcile technological promise with the complex realities of marginalized educational landscapes.

3. Research Methodology

3.1 Theoretical Framework

This study is anchored in an integrated theoretical framework that bridges principles of vocabulary acquisition, technological innovation in language learning, and socio-technical contextualization. By synthesizing these perspectives, the research examines how AI-mediated

tools shape vocabulary learning outcomes for Yemeni EFL students, while accounting for the infrastructural and cultural realities of conflict-affected environments.

Vocabulary Acquisition Theory forms the pedagogical foundation, emphasizing the cognitive and contextual processes underpinning effective vocabulary mastery. As posited by Zeng et al. (2022) and Eskandari et al. (2024), vocabulary retention and application are influenced by linguistic characteristics (e.g., word frequency, polysemy) and instructional strategies that prioritize contextualization, repetition, and active engagement. For instance, Zhou and Wu (2024) demonstrate that learners who generate personalized contexts for new vocabulary achieve deeper retention compared to passive memorization. This aligns with AI tools' capacity to deliver adaptive exercises (e.g., ChatGPT's contextual sentence generation) and spaced repetition systems (e.g., Duolingo's gamified quizzes), which operationalize these principles by embedding words in meaningful, interactive scenarios.

Technology-Enhanced Language Learning (TELL) extends this foundation by highlighting how digital tools amplify pedagogical efficacy through personalization, interactivity, and immediacy. Hao et al. (2021) and Agrawal (2024) underscore that technologies like AI chatbots and adaptive platforms foster engagement by tailoring content to individual proficiency levels, providing real-time feedback, and simulating real-world language use. For example, Grammarly's instant corrections and Duolingo's adaptive algorithms exemplify TELL's core tenets, enabling learners to practice vocabulary in dynamic, low-pressure environments. In this study, TELL justifies the investigation of AI tools' ability to replicate—or surpass—the interactivity and personalization of traditional methods, particularly in settings where classroom resources are scarce.

Socio-Technical Systems Theory contextualizes the implementation of these technologies within Yemen's conflict-affected landscape. As argued by Crompton et al. (2024) and Evenddy (2024), technological interventions must account for infrastructural constraints (e.g., unstable internet access), economic barriers (e.g., high software costs), and cultural relevance to achieve equitable adoption. In Yemen, where 64% of learners face financial barriers to AI tools and 57.3% struggle with connectivity, the theory shifts focus from technological potential alone to its intersection with local realities. For instance, AI tools lacking Arabic contextualization or offline functionality may exacerbate inequities despite their pedagogical strengths. This lens ensures the study critically evaluates not only AI's effectiveness but also its feasibility and inclusivity in resource-constrained contexts.

The interplay of these theories creates a holistic lens to analyze AI-mediated vocabulary learning. Vocabulary Acquisition Theory and TELL elucidate how AI tools enhance learning through personalized, interactive methods, while Socio-Technical Systems Theory explains why certain tools succeed or falter in Yemen's specific context.

This framework not only guides the analysis of AI's comparative advantages but also informs recommendations for designing tools that balance innovation with socio-cultural sensitivity. By grounding the study in these theories, the research advances a nuanced understanding of AI's role in language education within marginalized, high-stakes environments.

3.2 Instruments

The primary data collection instrument utilized in this study was a questionnaire designed to gather both quantitative and qualitative data regarding students' experiences with AI-enhanced vocabulary learning. The questionnaire was structured into three main sections.

The first section focused on demographics, collecting participants' age, gender, academic level, and prior experience with technology-enhanced learning tools. This information provided valuable context for interpreting the subsequent responses.

The second section employed a Likert-scale format to assess participants' perceptions of the usefulness, ease of use, and engagement levels of various AI tools, such as Duolingo and ChatGPT. Additionally, this section gathered data on the frequency and duration of usage for these tools, providing insights into the extent of their adoption.

The third section comprised open-ended questions, allowing participants to share qualitative insights into the benefits, challenges, and suggestions for improving AI tools within the context of Yemen. This section facilitated a deeper understanding of the participants' experiences and perspectives, complementing the quantitative data collected in the previous sections.

To ensure the validity and reliability of the data collection instrument, several measures were taken. First, a pilot testing phase was conducted with 15 students to refine the clarity and cultural appropriateness of the questionnaire items. Second, Cronbach's alpha was calculated for the Likert-scale items, yielding a reliability coefficient of 0.84, indicating a high level of internal consistency. Finally, three EFL (English as a Foreign Language) educators reviewed the content of the questionnaire, assessing its validity in measuring the intended constructs.

3.3 Ethical Consideration

Informed consent was secured from all participants at the beginning of the survey through a written consent form. The form outlined the study's purpose, emphasized voluntary participation, clarified confidentiality measures, and assured participants of their right to withdraw without penalty.

3.4 Data Analysis

The data analysis process employed in this study involved a robust mixed-methods approach, combining quantitative and qualitative techniques to provide a comprehensive understanding of the research findings.

The qualitative analysis involved a rigorous six-phase thematic analysis approach applied to the open-ended responses provided by the participants. The first phase, familiarization, involved repeated readings of the Arabic and English transcripts to identify potential patterns and gain a deeper understanding of the data. In the second phase, two bilingual researchers independently generated descriptive codes for the data, capturing nuances such as "High app costs limit access."

The third phase involved the development of a codebook, where the identified codes were categorized into broader themes, such as "Socioeconomic Barriers," with clear definitions and

examples to ensure consistency in the coding process. To ensure the reliability of the qualitative analysis, inter-rater reliability was assessed using Cohen's Kappa, which yielded a strong agreement score of 0.82. Any discrepancies or disagreements between the two researchers were resolved through consensus.

In the fifth phase, the themes and subthemes were further refined and finalized, with subthemes such as "Infrastructural Challenges: Unstable internet" emerging from the data. Finally, the qualitative findings were triangulated with the quantitative data, allowing for a comprehensive integration of the results and providing a holistic understanding of the research topic.

For the quantitative analysis, descriptive statistics were calculated to summarize participants' perceptions of AI tools for vocabulary learning. Additionally, inferential statistical tests, such as independent t-tests and ANOVA, were conducted to examine potential differences in perceptions based on demographic factors (see Table 6).Furthermore, Cronbach's alpha, with a coefficient of 0.84, was calculated to confirm the reliability and internal consistency of the Likert-scale items used in the questionnaire.

This mixed-methods approach ensured a robust and comprehensive analysis, leveraging the strengths of both quantitative and qualitative techniques to provide a holistic understanding of students' experiences with AI-enhanced vocabulary learning. 4. Results and Data Analysis

4.1 Demographic Information (N=75)

Table 1. Participants' Demographic Characteristics

Demographic Variable	Categories	Frequency (N)	Percentage (%)
Age	18–20	12	16%
	21–23	33	44%
	24–26	17	22.7%
	Over 26	13	17.3%
Gender	Male	24	32%
	Female	49	65.3%
	Prefer not to say	2	2.7%
Year of Study	First Year	11	14.7%
	Second Year	12	16%
	Third Year	18	24%
	Fourth Year	34	45.3%
English Proficiency	Beginner	8	10.7%
	Intermediate	40	53.3%
	Advanced	27	36%
Internet Access	Daily	56	74.7%
	3–5 times/week	8	10.7%
	Rarely	9	12%
	Only at university	2	2.7%

Table 1 summarizes the demographic characteristics of 75 participants. The majority (44%) were aged 21–23 years, followed by those aged 24–26 (22.7%), over 26 (17.3%), and 18–20 (16%). Females comprised 65.3% of the sample, males 32%, and 2.7% preferred not to disclose their gender. Participants were predominantly fourth-year students (45.3%), with smaller proportions in third year (24%), second year (16%), and first year (14.7%). Regarding English proficiency, most participants reported intermediate (53.3%) or advanced (36%) skills, while only 10.7% identified as beginners. A large majority (74.7%) accessed the internet daily, with smaller groups reporting access 3–5 times per week (10.7%), rarely (12%), or only at university (2.7%). The data reflect a sample skewed toward younger, female, senior-year participants with strong English proficiency and frequent internet use.

4.2 RQ1: How Do Yemeni EFL Learners Use AI Tools to Enhance Their English Vocabulary?

Table 2. AI Tools Usage Patterns

AI Tools Used	Frequency (N)	Percentage (%)
ChatGPT	55	73.3%
Duolingo	39	52%
Grammarly	24	32%
Vocablet	10	13.3%
Quizlet	10	13.3%
Kahoot	9	12%

Table 2 examines the frequency of AI tool usage among participants, their primary purposes for engaging with these tools, and the features they value most. The data reveals distinct trends in tool adoption, application preferences, and feature prioritization, offering insights into user behaviour and potential implications for educational or technological design.

ChatGPT dominates usage, with 73.3% of participants reporting its use, far surpassing other tools. This highlights its broad applicability, likely for tasks like content generation, problem-solving, or conversational interaction. Duolingo ranks second (52%), reflecting its popularity in language learning, particularly for gamified vocabulary and grammar exercises. Grammarly (32%) follows, likely leveraged for writing assistance, while Vocablet, Quizlet, and Kahoot show limited adoption (≤13.3%), suggesting niche or situational use (e.g., classroom activities). This suggests that general-purpose tools and language-focused platforms are prioritized over-specialized or classroom-oriented tools, possibly due to their versatility or alignment with independent learning goals.

The dominance of ChatGPT (73.3%) and Duolingo (52%) aligns with Vocabulary Acquisition Theory, which prioritizes contextualized, repetitive, and interactive exposure to new vocabulary (Zeng et al., 2022; Zhou & Wu, 2024). ChatGPT's ability to generate contextual sentences and simulate conversational interactions operationalizes this theory by embedding vocabulary in meaningful, real-world scenarios. Similarly, Duolingo's gamified quizzes

leverage spaced repetition and task-based learning principles central to effective vocabulary retention (Eskandari et al., 2024). The limited adoption of specialized tools like Kahoot (12%) and Vocablet (13.3%) suggests that learners prioritize platforms offering broad contextual utility over niche applications, reinforcing the theory's emphasis on adaptable, learner-driven practice.

Among the primary usage purposes, gamified learning is the top motivator, with 54.7% using AI tools for games/quizzes, underscoring the appeal of interactive and engaging formats. Vocabulary quizzes/tests (42.7%) and interactive chatbots (36%) follow, emphasizing participants' focus on language acquisition and conversational practice. This aligns with pedagogical strategies that prioritize active, experiential learning by integrating play and interactivity into the learning process.

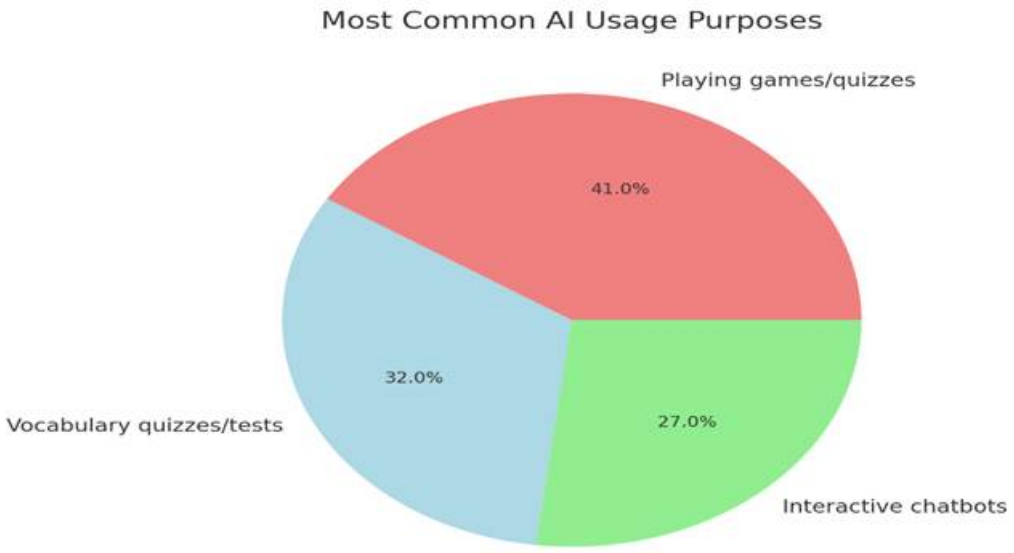

Figure 1. Most common AI Usage purposes

The data aligns with the TELL (Technology-Enhanced Language Learning) framework, which highlights learners' inclination towards tools that offer personalization, interactivity, and immediacy (Hao et al., 2021; Agrawal, 2024). This preference is evident in several key findings: The popularity of gamified learning features (54.7% used AI tools for games/quizzes) resonates with TELL's emphasis on fostering engagement through interactive formats, exemplified by the points and level systems in applications like Duolingo. The substantial usage of interactive chatbots (36%) corresponds with TELL's focus on simulating human-like interactions, enabling learners to practice vocabulary in conversational contexts through tools such as ChatGPT. The high value placed on instant feedback (37.3%) aligns with TELL's principle of immediate guidance, as seen in Grammarly's real-time corrections, which accelerate error correction and reinforce retention. These findings highlight how AI tools

embody TELL's promise of transcending traditional methods by delivering dynamic, self-paced learning experiences tailored to individual needs and preferences.

Regarding the most valued AI features, personalized quizzes and speech recognition tie as the most valued (49.3% each), highlighting demand for adaptive, tailored content and tools supporting oral language skills. Contextual examples (48%) and instant feedback (37.3%) are also prioritized, suggesting users value clarity in application (e.g., vocabulary in context) and real-time guidance. This indicates that personalization and interactivity are critical to user satisfaction, with a strong preference for features that simulate human-like interaction or provide actionable insights.

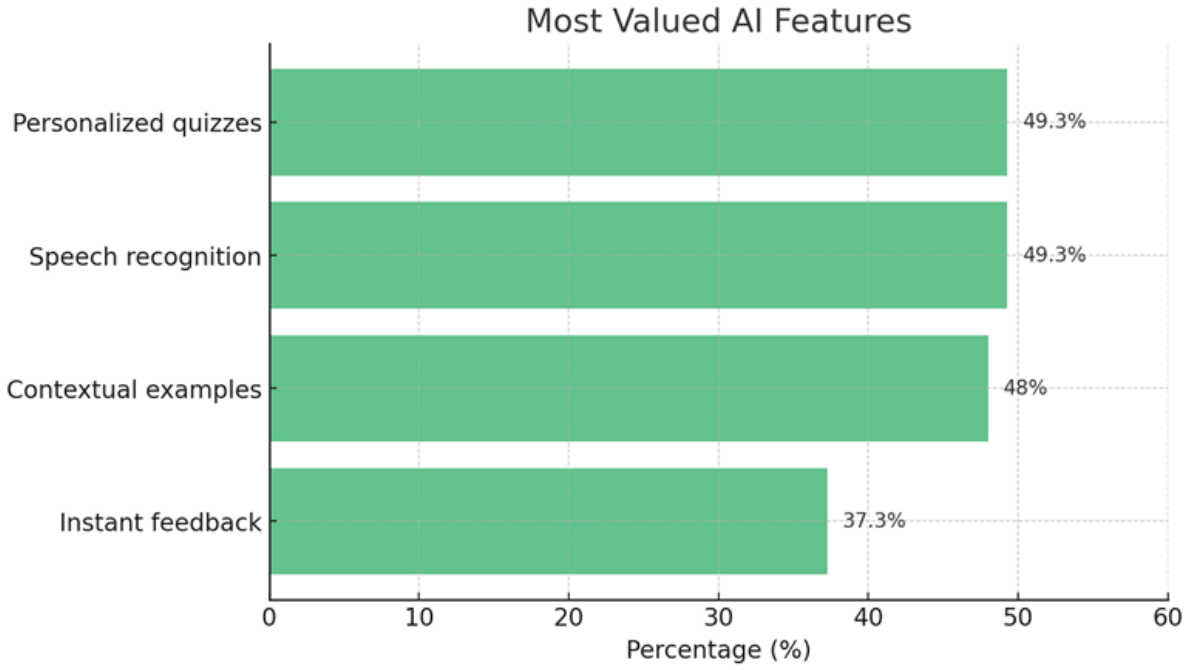

Figure 2. Participants' perceptions on most valued AI features

In synthesizing these findings, the dominance of ChatGPT and Duolingo suggests users favor tools that combine versatility, accessibility, and engagement. Developers of specialized tools may need to enhance adaptability for independent use. The focus on gamification and interactivity signals opportunities for educators to integrate AI tools that make learning dynamic and self-paced, particularly in language education. Prioritizing personalization, speech recognition, and contextual learning could enhance tool adoption and effectiveness, especially for users seeking autonomous, skill-specific practice.

While the findings affirm AI's pedagogical advantages, the Socio-Technical Systems Theory provides a lens to understand the barriers limiting tool adoption and effectiveness in Yemen's context:

Tool Selection: Learners' preferences for ChatGPT and Duolingo—versatile, low-cost platforms—reflect adaptations to infrastructural limitations (e.g., 57.3% faced unstable internet) and economic constraints (64% cited high app costs), as highlighted by Crompton et al. (2024). Specialized tools like Kahoot, often requiring classroom coordination or stable connectivity, are less feasible in Yemen's conflict-affected environment.

Feature Priorities: The high demand for offline functionality (56%) and speech recognition capabilities (49.3%) underscores learners' efforts to mitigate socio-technical challenges. For instance, speech recognition tools like Duolingo's pronunciation exercises address oral practice gaps in teacher-scarce settings. However, their effectiveness hinges on reliable internet access—a systemic hurdle prevalent in Yemen. The Socio-Technical Systems Theory sheds light on how learners' tool choices and feature preferences are shaped by the unique socio-economic and infrastructural realities of conflict-affected regions, necessitating tailored solutions that accommodate these contextual constraints.

4.3 RQ2: What Socio-Technical Challenges Impede Adopting AI-driven Vocabulary Learning in Yemen?

Table 3. Challenges Faced by Learners

Challenges	Frequency (N)	Percentage (%)
High cost of apps/software	48	64%
Unstable internet connection	43	57.3%
Lack of guidance/training	22	29.3%
AI content not culturally relevant	20	26.7%
Technical issues (app crashes)	14	18.7%

The table highlights the primary obstacles learners encounter when engaging with AI tools or digital learning platforms. The data reveal significant barriers to accessibility, equity, and usability, with implications for educators, developers, and policymakers.

The high cost of apps/software emerges as the most prevalent challenge (64%), indicating financial barriers to accessing premium tools. Unstable internet connection follows closely (57.3%), underscoring infrastructural limitations that hinder consistent participation. Lack of guidance/training (29.3%) and cultural irrelevance of AI content (26.7%) reflect gaps in user support and localization. Technical issues like app crashes are less common (18.7%) but still disrupt the learning process. Economic and infrastructural barriers dominate the hierarchy of challenges, with educational, cultural gaps, and technical reliability concerns being secondary but notable issues.

The prevalence of high costs (64%) and unstable internet (57.3%) underscores the socio-technical realities of Yemen's conflict-affected context. These barriers reflect systemic inequities where financial constraints and infrastructural deficits limit access to premium AI tools, reinforcing a digital divide. For instance, learners' reliance on free or pirated versions of

apps (with restricted features) aligns with Crompton et al.'s (2024) assertion that economic barriers disproportionately marginalize low-income populations, undermining the TELL principle of equitable access to adaptive technologies. Similarly, unstable internet connectivity disrupts the Vocabulary Acquisition Theory's emphasis on consistent, contextualized practice, as learners cannot reliably engage with tools like ChatGPT or Duolingo.

The findings carry significant implications. Regarding economic accessibility, the high cost suggests many learners rely on free versions with limited features or pirated tools, risking inequitable access to quality resources. Developers could adopt tiered pricing, scholarships, or partnerships with educational institutions to subsidize costs. Unstable internet disproportionately affects learners in regions with poor connectivity or low-income backgrounds, exacerbating educational disparities. Tools should prioritize offline functionality and low-bandwidth compatibility to address infrastructure limitations.

Nearly 30% of learners struggle with insufficient guidance, signaling a need for onboarding tutorials or mentorship programs to enhance user support. The cultural irrelevance of AI-generated content (26.7%) implies a lack of contextual or linguistic alignment with learners' backgrounds, reducing engagement. Incorporating localized content and multilingual support could address this gap. While app crashes are less frequent, they erode trust in digital tools, necessitating robust testing and user feedback loops to improve stability.

The lack of guidance/training (29.3%) and cultural irrelevance (26.7%) highlight misalignments between AI tool design and learner needs. While TELL emphasizes user-friendly, interactive platforms (Hao et al., 2021), the absence of onboarding tutorials or mentorship programs leaves learners unprepared to leverage AI's full potential. For example, tools like Grammarly or ChatGPT require digital literacy to navigate advanced features, which many Yemeni students lack due to limited exposure. Additionally, AI-generated content often fails to incorporate culturally relevant examples (e.g., Arabic-English contextualization), reducing its utility for learners seeking vocabulary applicable to their daily lives. This disconnect violates TELL's principle of contextualized learning, which is critical for retention and active usage (Zhou & Wu, 2024).

Even minor technical issues (18.7% app crashes) can disrupt the spaced repetition and contextual immersion central to vocabulary retention. For instance, interruptions in gamified quizzes (used by 54.7%) or interactive chatbots (36%) hinder learners' ability to build lexical knowledge through repeated, meaningful exposure—a cornerstone of Vocabulary Acquisition Theory (Zeng et al., 2022). Furthermore, the reliance on traditional methods by 34.7% of learners (Table 4) signals a regression to static, decontextualized learning when AI tools fail, undermining progress in active vocabulary usage.

To synthesize, stakeholders must address affordability by promoting freemium models with essential features free and advocating for institutional licenses or government-funded access in underserved areas. Enhancing accessibility involves optimizing tools for offline use, low internet dependency, and developing lightweight apps for low-end devices. Improving localization and training requires co-creating content with educators from diverse cultural contexts and integrating in-app tutorials or chatbots for real-time guidance. Strengthening

technical infrastructure entails partnering with telecom providers to improve internet access in marginalized regions and prioritizing user-reported bugs for faster resolution.

In conclusion, the data underscore systemic challenges in digital learning, where financial and infrastructural barriers overshadow technical or pedagogical limitations. To bridge these gaps, stakeholders must adopt a learner-centric approach that prioritizes affordability, accessibility, and cultural inclusivity. Addressing these issues could democratize access to AI-driven education, particularly for marginalized or low-income populations.

Table 4. Strategies to Overcome Challenges

Strategy	Frequency	Percentage (%)
Using offline app features	42	(56%)
Asking peers/teachers	30	(40%)
Switching to traditional methods	26	(34.7%)
Daily practice	26	(34.7%)

This analysis examines the strategies adopted by learners to address the barriers outlined in Table 4, revealing a mix of practical, social, and adaptive approaches. The strategies Yemeni EFL learners employ to overcome barriers in AI-mediated vocabulary learning reflect a dynamic interplay of Socio-Technical Systems Theory, Technology-Enhanced Language Learning (TELL), and Vocabulary Acquisition Theory. These adaptive approaches highlight both learner resilience and systemic gaps, offering insights into how theoretical principles manifest—and falter—in conflict-affected contexts.

The predominant use of offline app features (56%) directly addresses infrastructural barriers like unstable internet (57.3%), exemplifying learners' pragmatic adaptations to socio-technical challenges. This strategy aligns with Crompton et al.'s (2024) assertion that technological solutions must account for contextual realities. Tools lacking offline capabilities exclude learners in low-connectivity regions, violating the Socio-Technical Systems Theory principle that technology must align with local infrastructural conditions. For instance, while Duolingo's offline mode sustains practice during connectivity outages, apps reliant on real-time AI interactions (e.g., ChatGPT) become inaccessible, forcing learners to revert to traditional methods.

The reliance on peer/teacher support (40%) to counter lack of guidance (29.3%) underscores TELL's emphasis on collaborative, interactive learning (Hao et al., 2021). While informal networks compensate for institutional shortcomings, they reflect a gap in structured pedagogical support. For example, learners using ChatGPT for conversational practice may turn to peers to interpret complex outputs, mimicking TELL's ideal of social learning but lacking scalability. Learners rely on informal networks to compensate for inadequate institutional support, underscoring the role of the community in bridging knowledge gaps. While peer-driven learning can supplement formal training, it may not replace structured

guidance.

The switch to traditional methods (34.7%)—driven by high costs (64%) and technical issues (18.7%)—reveals a tension between innovation and accessibility. While traditional methods (e.g., textbooks) lack the personalization and interactivity central to Vocabulary Acquisition Theory, they remain indispensable in resource-scarce settings. This regression underscores Socio-Technical Systems Theory's warning that economic and infrastructural barriers can nullify pedagogical advancements. For instance, learners may abandon AI tools like Grammarly (32% usage) due to costs, reverting to rote memorization—a method less effective for retention (Zeng et al., 2022).

Daily practice (34.7%) reflects learner determination, a cornerstone of Vocabulary Acquisition Theory's emphasis on repetition and engagement. However, systemic barriers (e.g., sporadic internet) force learners to rely on sheer persistence, often without optimal tools. This aligns with TELL's critique that motivation alone cannot overcome structural inequities (Siregar et al., 2024). For example, learners practicing vocabulary via unstable apps may experience inconsistent progress, undermining retention.

Evaluating the strengths and limitations of these strategies reveals a need for stakeholder interventions. Offline features mitigate connectivity gaps but require apps to offer offline functionality. Peer and teacher support fosters collaboration as a low-cost solution, but quality depends on the expertise of those involved. Traditional methods are accessible and avoid tech-related issues but lack the benefits of AI-driven tools. Daily practice builds discipline but may strain learners without adequate resources.

To address these challenges, recommendations for stakeholders include promoting offline-first tools, strengthening peer networks, and blending traditional and digital methods for educators and institutions. Developers should prioritize offline functionality, design for low-resource settings, and embed community features within apps. Policymakers can subsidize digital tools, partner with edtech firms to provide free or discounted licenses and invest in improving internet access and affordable devices in underserved regions.

While learners' strategies emphasize adaptability and resourcefulness, particularly in low-resource environments, these workarounds are reactive rather than transformative. To address challenges sustainably, systemic solutions like affordable internet and subsidized tools must complement individual efforts. Hybrid learning models that merge digital and traditional methods can balance accessibility and innovation, and community-driven support should be formalized to ensure equitable access to guidance.

In conclusion, learners' strategies reveal a dialectic between agency and constraint—while they adapt resourcefully to socio-technical barriers, their workarounds underscore systemic failures. Grounded in Socio-Technical Systems Theory, the analysis calls for solutions that harmonize TELL's interactive potential with Vocabulary Acquisition Theory's pedagogical rigor. By addressing infrastructural and economic inequities, stakeholders can transform reactive adaptations into sustainable, equitable learning ecosystems. This approach not only bridges gaps in Yemen's educational landscape but also offers a blueprint for AI integration in

conflict-affected regions globally.

4.4 RQ3: How Does AI-mediated Vocabulary Learning Compare to Traditional Methods in Improving Retention and Active Usage Among Yemeni Students?

Table 5. Comparative Effectiveness of AI Tools

Statements	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
Improved my vocabulary retention	37.3%	33.3%	24%	4%	1.3%
More engaging than traditional methods	38.7%	30.7%	21.3%	9.3%	0%
Relevant to academic and daily life	29.3%	42.7%	22.7%	5.3%	0%
Increased confidence using English	28%	41.3%	17.3%	10.7%	2.7%
Encourages regular practice	21.3%	44%	17.3%	13.3%	4%
Preference over traditional methods	28%	33.3%	22.7%	10.7%	5.3%
Overall, AI better compared to traditional methods	41.3%	32%	21.3%	5.3%	0%

The data presented in Table 5 reveal that a significant majority of Yemeni students perceive AI-mediated vocabulary learning as more effective than traditional methods in enhancing retention and active language use. Approximately 70.6% of participants agreed or strongly agreed that AI tools improved their vocabulary retention, with 69.4% finding these tools more engaging than conventional approaches. This suggests that features such as gamification, interactive chatbots, and personalized feedback—common in platforms like ChatGPT and Duolingo—resonate with learners by making the process dynamic and immersive. Furthermore, 72% of respondents viewed AI tools as relevant to both academic and daily life, underscoring their practical utility in real-world contexts. Confidence in using English also saw a boost, with 69.3% attributing increased self-assurance to AI-mediated practice, likely due to features like speech recognition and contextual examples that simulate authentic communication.

Despite these advantages, the findings highlight nuanced challenges. While 73.3% of students overall endorsed AI tools as superior to traditional methods, a notable minority remained unconvinced. For instance, 24% were neutral about AI's impact on retention, and 21.3% expressed neutrality regarding its overall superiority. This ambivalence may stem from infrastructural and socioeconomic barriers prevalent in Yemen, such as unstable internet access (reported by 57.3% in Table 3) and the high cost of apps (cited by 64%). These obstacles likely limit consistent access to AI tools, pushing some learners toward traditional methods like textbooks or in-person instruction, which are more accessible but lack the interactivity and personalization of AI. Cultural relevance also emerged as a concern, with 26.7% of participants in Table 3 noting that AI-generated content did not align with their local context, potentially diminishing its perceived value compared to regionally tailored resources.

The comparison between AI and traditional methods reflects a tension between innovation and accessibility. Traditional approaches, while familiar and free from tech-related barriers, are often criticized for being static and less adaptive. In contrast, AI tools offer real-time feedback and engagement but require reliable infrastructure and financial resources—conditions not universally met in Yemen. For example, while 65.3% of learners reported that AI encouraged regular practice, 17.3% remained neutral or resistant, indicating that motivational or usability gaps persist. This dichotomy underscores the importance of hybrid models that blend AI's strengths with traditional methods' accessibility. Educators could integrate AI tools for interactive practice while using textbooks for foundational theory, ensuring equitable access for students facing connectivity or cost barriers.

For AI tools to reach their full potential in this context, developers and policymakers must address systemic challenges. Localizing content to include Yemeni cultural references and Arabic-English contextual examples could enhance relevance and engagement. Simultaneously, expanding offline functionality and advocating for subsidized access to premium features would mitigate infrastructural and economic hurdles. Ultimately, the data suggest that AI-mediated learning holds promise for transforming language education in Yemen, but its success hinges on tailored solutions that acknowledge the region's unique socioeconomic realities and bridge the gap between technological innovation and equitable access.

4.5 Inferential Statistics: Differences Based on Demographics

Table 6. Results of Independent *t*-Tests and ANOVA

Demographic Factor	Test Type	Comparison Groups	*t*/*F* Value	*p*-value	Significance
Gender	Independent *t*	Male vs. Female	$t = 2.34$	0.022*	Significant
Age	ANOVA	18–20, 21–23, 24–26, Over 26	$F = 3.12$	0.031*	Significant
English Proficiency	ANOVA	Beginner, Intermediate, Advanced	$F = 4.05$	0.021*	Significant

Note. $p < 0.05$.

The inferential statistical analyses revealed significant differences in perceptions of AI tools based on gender, age, and English proficiency. For instance, female participants reported higher engagement with AI tools compared to males ($t = 2.34$, $p = 0.022$), while advanced learners perceived AI tools as more effective than beginners ($F = 4.05$, $p = 0.021$). These findings highlight the nuanced role of demographic variables in shaping AI adoption and effectiveness.

5. Discussion

This study sought to address how AI-mediated vocabulary learning compares to traditional methods in improving retention and active usage among Yemeni students by examining learners' perceptions, practices, and challenges. Grounded in an integrated theoretical framework—Vocabulary Acquisition Theory, Technology-Enhanced Language Learning

(TELL), and Socio-Technical Systems Theory—the findings extend the literature by contextualizing AI's role in a conflict-affected setting like Yemen while revealing critical tensions between technological potential and systemic inequities.

The high endorsement of AI tools (73.3%) aligns with Vocabulary Acquisition Theory, which emphasizes contextualized, repetitive, and interactive exposure as key drivers of lexical mastery (Zeng et al., 2022). Tools like ChatGPT and Duolingo operationalize this theory through gamified quizzes (54.7%) and interactive chatbots (36%), which embed vocabulary in real-world scenarios. For instance, learners' preference for personalized quizzes (49.3%) and contextual examples (48%) mirrors Zhou and Wu's (2024) findings on the efficacy of learner-generated contexts. These features likely underpinned the reported improvements in retention (70.6%) and confidence (69.3%), demonstrating how AI tools align with cognitive strategies for vocabulary retention. However, the reliance on traditional methods by 34.7% of learners during disruptions highlights gaps in sustaining contextual immersion, a cornerstone of this theory.

The dominance of AI tools like ChatGPT (73.3%) and Duolingo (52%) reflects TELL's principles of personalization, immediacy, and interactivity (Hao et al., 2021). Participants valued instant feedback (37.3%) and speech recognition (49.3%), features that exemplify TELL's capacity to transcend classroom limitations through adaptive, real-time support (Agrawal, 2024). These tools' ability to simulate human-like interactions (e.g., conversational chatbots) aligns with Siregar et al.'s (2024) assertion that engagement hinges on dynamic, self-paced environments. Yet, the lack of structured guidance (29.3%) and culturally irrelevant content (26.7%) underscores a misalignment between TELL's ideals and implementation, particularly in contexts where digital literacy and localization are overlooked.

The systemic barriers of high costs (64%) and unstable internet (57.3%) underscore the socio-technical realities of Yemen's conflict-affected context. These challenges, as posited by Crompton et al. (2024), reflect how infrastructural deficits and economic inequities nullify technological potential, forcing learners to adopt reactive strategies like offline features (56%) or peer networks (40%). The cultural irrelevance of AI content further violates Socio-Technical Systems Theory's emphasis on contextual alignment, as tools lacking Arabic-English contextualization fail to meet learners' linguistic and daily-life needs (Evenddy, 2024). This duality—where learners praise AI's efficacy yet revert to traditional methods—exemplifies the theory's warning that technology must harmonize with local realities to achieve equity.

The findings reveal a tension between AI's pedagogical promise and its socio-technical feasibility. While Vocabulary Acquisition Theory and TELL explain AI's strengths in retention and engagement, Socio-Technical Systems Theory contextualizes why adoption remains fragmented. For example, offline functionality (56%) mitigates connectivity gaps but highlights infrastructural neglect, while peer networks (40%) compensate for institutional voids but lack scalability. These insights necessitate a learner-centric approach that balances innovation with accessibility.

The study's findings are consistent with Hao et al. (2021) and Hezam et al. (2024), who highlighted AI's capacity for engagement and adaptability. 73.3% of Yemeni learners endorsed

AI tools as superior to traditional methods, citing features like gamified quizzes (54.7%) and interactive chatbots (36%). These tools' ability to simulate real-world interactions (e.g., speech recognition, contextual examples) aligns with Agrawal's (2024) emphasis on personalization, as 49.3% of participants valued tailored quizzes and 48% appreciated contextual examples. Such adaptability likely contributed to the reported improvements in retention (70.6% agreement) and confidence (69.3% agreement), reinforcing Siregar et al.'s (2024) findings on AI-driven retention strategies.

However, the study also underscores critical socio-technical barriers that mirror concerns raised by Crompton et al. (2024) and Evenddy (2024). The dominance of economic (64% cited high costs) and infrastructural challenges (57.3% unstable internet) reflects systemic inequities that hinder access to premium AI features, exacerbating the digital divide. Furthermore, 26.7% criticized AI content for lacking cultural relevance, echoing Evenddy's (2024) call for localized pedagogical materials. These barriers contextualize why 34.7% of learners occasionally reverted to traditional methods, despite acknowledging AI's advantages—a tension not fully explored in prior studies.

The study highlights the need for localized AI solutions co-designed with Yemeni educators to incorporate regional dialects, cultural references, and academic needs. Policy interventions like subsidized internet access and institutional partnerships are necessary to democratize access to AI tools. Longitudinal research tracking how AI adoption impacts long-term retention and language proficiency in conflict zones is also recommended.

In conclusion, despite infrastructural and economic constraints, AI-mediated vocabulary learning demonstrates significant promise for Yemeni EFL learners, enhancing engagement, retention, and confidence. However, its full potential requires addressing systemic inequities through culturally grounded, learner-centric innovations. This study thus advances the theoretical discourse on AI in education by foregrounding the interplay between technological affordances and socioeconomic realities in marginalized contexts.

6. Limitations of the Study

While this study offers critical insights into AI-enhanced vocabulary learning in Yemen's conflict-affected context, several limitations must be acknowledged. First, the sample size (N=75)—though sufficient for exploratory analysis—limits the generalizability of findings, particularly given Yemen's fragmented educational landscape, where access to technology and language proficiency vary widely across regions. Second, reliance on self-reported data introduces potential biases, such as social desirability or recall inaccuracies. Finally, the study focused on university-level learners, excluding younger students or those in non-formal education systems, which restricts the applicability of results to broader populations.

To advance this line of inquiry, future research should adopt mixed-methods longitudinal designs that triangulate self-reported data with objective measures and qualitative insights. Region-specific adaptations, co-developed with educators and community partners, are vital for untangling AI's transformative potential in marginalized educational settings worldwide. Only through such rigorous and context-sensitive approaches can we fully harness AI's power

to revolutionize language learning in even the most challenging environments.

7. Conclusion

This study underscores the transformative potential of AI-mediated vocabulary learning for Yemeni EFL learners, with 73.3% endorsing AI tools as superior to traditional methods. Features like gamification, interactive chatbots, and personalized feedback resonate with learners, enhancing engagement, retention, and confidence. However, the full realization of AI's benefits is contingent upon addressing systemic barriers prevalent in Yemen's conflict-affected context.

The findings emphasize the need for a learner-centric approach that prioritizes affordability, accessibility, and cultural inclusivity. Economic constraints, with 64% citing high costs, and infrastructural limitations, with 57.3% reporting unstable internet, emerged as significant obstacles hindering equitable access to premium AI features. Furthermore, 26.7% criticized AI content for lacking cultural relevance, underscoring the importance of localized, contextually appropriate solutions.

To bridge these gaps, stakeholders must adopt a multi-pronged strategy. Developers should prioritize offline functionality, tiered pricing models, and co-creation with local educators to incorporate regional dialects and cultural references. Policymakers can subsidize internet access, advocate for institutional partnerships, and promote government-funded access to AI tools in underserved areas. Educators can integrate AI into curricula, formalize peer-driven learning networks, and implement hybrid models blending AI with traditional instruction.

Ultimately, this study advances the theoretical discourse on AI in education by foregrounding the interplay between technological affordances and socioeconomic realities in marginalized contexts. While AI-mediated vocabulary learning holds significant promise, its success hinges on tailored solutions that acknowledge the unique challenges and opportunities present in conflict-affected regions like Yemen. By addressing systemic inequities through culturally grounded, learner-centric innovations, AI can become a powerful catalyst for transforming language education and empowering learners in even the most challenging environments.

To advance this field, researchers should design longitudinal studies that integrate objective metrics (e.g., vocabulary retention tests) alongside qualitative feedback. This dual-method approach would validate learners' perceived benefits of AI tools with empirical data, addressing the current gap in comparative effectiveness research.

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