



Leveraging Digital Technologies for Effective Vocabulary Acquisition

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DOI: <https://doi.org/10.36892/ijlls.v8i5.2736>

APA Citation: Boasiako, A., Kusi, P. H., & Owusu, E. (2026). Leveraging Digital Technologies for Effective Vocabulary Acquisition. *International Journal of Language and Literary Studies*, 8(5).389-400. <https://doi.org/10.36892/ijlls.v8i5.2736>

Received:

14/07/2026

Accepted:

25/08/2026

Keywords:

Digital Tools,
Language
Learning,
Vocabulary
Development,
Smartphones

Abstract

This study investigated how digital tools, such as mobile applications, online dictionaries, and e-learning platforms, affected vocabulary acquisition in terms of retention, motivation, and practical usage, compared to traditional methods. A quasi-experimental mixed-methods design was adopted. The study involved a purposive sampling of 60 students from two selected senior high schools in Ghana. The paper is grounded in Nation's Lexical Knowledge Framework, Mayer's Cognitive Theory of Multimedia Learning, and Vygotsky's Sociocultural Theory. The data were collected through pre- and post-vocabulary tests, questionnaires, and semi-structured interviews, which measured retention, motivation, and practical application. The outcomes revealed that students using digital tools achieved significantly higher vocabulary retention gains and reported increased motivation due to gamification, spaced repetition, and instant feedback. The study concluded that digitally mediated instruction, when pedagogically designed and fairly implemented, could significantly enhance vocabulary acquisition in the Ghanaian ESL setting. It is recommended that teacher training on tool selection should be provided. Also, educators should balance digital autonomy with guided instruction to ensure comprehensive lexical development. This research contributes to understanding technology-assisted vocabulary learning in Ghanaian senior high schools.

Introduction

1.1 Background

Vocabulary knowledge is widely acknowledged as one of the most important components of second language (L2) proficiency because it forms the foundation of effective communication and academic success. Learners require adequate vocabulary to comprehend spoken and written texts, express ideas clearly, and participate confidently in communicative activities. In English as a Second Language (ESL) contexts, vocabulary competence is particularly important because it supports the development of listening, speaking, reading, and writing skills. According to Nation (2001), knowing a word extends beyond recognising its meaning to understanding its pronunciation, grammatical behaviour, collocations, frequency, and appropriate use in different communicative contexts. Similarly, Read (2000) argues that vocabulary acquisition is a gradual process that develops through repeated exposure to words in meaningful situations rather than through isolated memorisation. Consequently, learners with limited vocabulary knowledge often experience difficulties in language comprehension, written expression, and overall academic performance.

Traditionally, vocabulary instruction has relied heavily on teacher-centred approaches such as word lists, translation, dictionary consultation, and rote memorisation. While these methods may facilitate short-term recall, they often provide limited opportunities for learners to engage actively with vocabulary or use newly acquired words in authentic contexts. Schmitt (2000) observes that successful vocabulary learning requires repeated encounters with lexical items through varied and meaningful activities that promote long-term retention and productive language use. In response to these limitations, advances in educational technology have introduced digital tools that create more interactive and learner-centred environments for vocabulary learning. Mobile applications, online dictionaries, and e-learning platforms provide multimedia resources, pronunciation models, immediate feedback, contextual examples, and spaced repetition, enabling learners to practise vocabulary beyond the traditional classroom.

Established learning theories support the pedagogical value of these digital technologies. Mayer's (2009) Cognitive Theory of Multimedia Learning proposes that learners achieve deeper understanding when information is presented through complementary verbal and visual channels. Likewise, Vygotsky's (1978) Sociocultural Theory emphasises that learning occurs through interaction, mediation, and appropriate scaffolding, all of which can be facilitated by technology-enhanced learning environments. Together, these perspectives suggest that digital tools can enhance vocabulary acquisition by promoting learner engagement, independent learning, and meaningful interaction with language.

Empirical research has increasingly demonstrated the effectiveness of technology-assisted vocabulary learning. Burston's (2015) meta-analysis of mobile-assisted language learning reported generally positive outcomes across diverse educational contexts, while Godwin-Jones (2018) argued that mobile technologies have become an integral part of contemporary language education by extending learning beyond classroom boundaries. More recently, Xodabande and Hashemi (2023) found that mobile-based learning significantly improved learners' vocabulary development through repeated lexical exposure and increased engagement. Similarly, Stockwell (2022) maintains that the educational benefits of mobile-assisted language learning depend on how effectively digital technologies are integrated into pedagogical practice rather than on technology alone. Collectively, these studies indicate that digital tools have considerable potential to support vocabulary acquisition when implemented within appropriate instructional frameworks.

In Ghana, English functions as the official language and the principal medium of instruction from the upper primary level through tertiary education. Consequently, students' academic achievement across all subjects depends largely on their ability to understand and use English effectively. Despite this central role, successive West African Examinations Council (WAEC) Chief Examiners' Reports continue to highlight persistent weaknesses in candidates' vocabulary usage, lexical choice, spelling, and written expression (WAEC, 2025). At the same time, increasing access to smartphones and internet-enabled learning resources has created new opportunities for integrating digital technologies into English language instruction. However, the extent to which these technologies improve vocabulary acquisition among Ghanaian senior high school students remains insufficiently understood. Existing research has focused predominantly on higher education or general technology adoption, with limited attention to vocabulary development in Ghanaian secondary schools.

In schools such as Adventist Senior High School, Bantama-Kumasi, and Twene Amanfo Senior High Technical School, Sunyani, traditional vocabulary-learning approaches have not adequately addressed these persistent challenges. Although digital tools, including mobile applications, online dictionaries, and e-learning platforms, are increasingly available to students, their effectiveness in promoting productive vocabulary development remains underexplored. Furthermore, factors such as internet accessibility, device availability, and teacher support may influence their educational value.

Against this background, the present study investigates the influence of digital tools on vocabulary acquisition among senior high school students in Ghana. Using a mixed-methods

approach, the study examines both the effectiveness of selected digital tools in improving vocabulary acquisition and students' experiences with their use. By providing empirical evidence from the Ghanaian senior high school context, the study contributes to the growing literature on technology-assisted language learning. It offers practical insights for English language teachers, curriculum developers, and educational policymakers seeking to improve vocabulary instruction through appropriate integration of digital technologies.

1.2 Objectives of the Research

The main objective is to examine how digital tools influence vocabulary acquisition among senior high school students.

Specific objectives are:

1. To assess the effectiveness of mobile applications, online dictionaries, and e-learning platforms on vocabulary retention.
2. To explore students' perceptions and experiences with these digital tools.
3. To identify challenges associated with using digital tools for word learning in senior high schools.

1.3 Research Questions

The research questions for the study are:

1. To what extent do digital tools improve vocabulary retention compared to traditional methods among senior high school students?
2. What are students' perceptions regarding the use of mobile applications, online dictionaries, and e-learning platforms for vocabulary learning?
3. What challenges do students encounter when using digital tools for vocabulary acquisition?

Literature Review

2.1. Introduction

This section reviews the theoretical frameworks, empirical studies, and research gaps relating to the use of digital tools for vocabulary acquisition. It provides the conceptual and empirical basis for examining the influence of digital tools on vocabulary development among senior high school students in Ghana.

2.2. Theoretical Frameworks

This study draws on the Cognitive Theory of Multimedia Learning (Mayer, 2002), which explains how learners process information better through combined visual and auditory channels, supported by digital tools. It is also grounded in Sociocultural Theory (Vygotsky, 1978), highlighting social interaction, and Nation's lexical framework, which focuses on a multidimensional approach to vocabulary acquisition and knowledge, emphasising that truly knowing a word involves far more than memorising its definition. The iPAC framework (Kearney et al., 2020) further guides analysis of personalisation, authenticity, and collaboration in mobile learning.

2.3. Empirical Studies on Digital Tools and Vocabulary Acquisition

Empirical research on digital tools for vocabulary acquisition has grown substantially, particularly with the rise of Mobile-Assisted Language Learning (MALL). Studies consistently report positive effects on retention, motivation, and learner autonomy, though results vary by context, tool design, and implementation. The Journal of Education and Learning Technology (a Ghanaian open-access journal) has emerged as an important venue for local scholarship in this area. The following sub-sections critically examine the empirical literature under three key categories relevant to the present study.

2.3.1 Digital Applications and Vocabulary Learning

Mobile applications have been widely investigated as tools for vocabulary development. Xodabande and Hashemi (2023) conducted a quasi-experimental study with university students using electronic textbooks delivered via mobile devices. They reported significant vocabulary gains due to portability, interactivity, and multimedia features that enabled repeated contextualised exposure. However, the study's focus (i.e., university learners) and a relatively short intervention period limit generalisability to senior high school contexts in resource-constrained settings like Ghana, where internet reliability is often inconsistent.

Rezaei et al. (2014) examined mobile applications among intermediate learners using a mixed-methods design. Post-intervention test scores improved, and questionnaire data indicated greater enjoyment, confidence, and participation compared to traditional methods. While the findings are encouraging, a lack of delayed post-test measures raises questions about long-term retention. Kayra (2024) described mobile applications as “a new paradigm in educational technology,” showing through questionnaires and interviews that gamified elements and spaced repetition enhanced retention beyond conventional wordlists. Kurd et al. (2023), similarly, found that multimodal presentation (pictures, audio, and example sentences) improved efficiency and catered to diverse learning styles. Robin and Aziz (2022) offered a broader view, demonstrating gains in both receptive and productive vocabulary when tools were integrated systematically.

Critically, these studies share a common strength in highlighting learner motivation but often suffer from self-report bias and limited attention to infrastructural barriers prevalent in Ghanaian senior high schools. Guo and Li (2022) added nuance by noting individual differences in usage frequency and self-regulation, recommending guided instruction alongside applications—an insight directly relevant to the present study's school-based intervention.

2.3.2 Digital Dictionary and Lexical Development

Research specifically on digital dictionaries and their role in lexical development is less extensive within the reviewed literature. Nevertheless, several studies indirectly address dictionary-like features embedded in mobile applications and e-learning platforms. Parvin (2020) advocated for dynamic e-learning platforms tailored to university-level EFL learners, emphasising personalised pathways that allow self-paced access to word meanings, collocations, and examples—functions akin to online dictionaries. The study's qualitative emphasis on learner autonomy is valuable; however, it lacks quantitative measures of lexical gains and was conducted in a university rather than a senior high school setting.

Xodabande and Hashemi (2023) noted that mobile electronic textbooks often incorporate dictionary functions (instant look-up, pronunciation, and contextual examples), contributing to deeper processing. Darkoah et al. (2024), published in the *Journal of Education and Learning Technology*, reported that technology-enhanced tools providing rich input and interactive practice supported second language acquisition, including lexical development, though infrastructural constraints moderated outcomes. Asante (2025) similarly found benefits for vocabulary and cognitive skills in Ghanaian bilingual settings but highlighted internet access as a limiting factor.

Critically, while these studies suggest digital dictionaries promote incidental learning and deeper lexical networks, few isolate dictionaries use from other mobile application features, making it difficult to attribute gains solely to lexical tools. In the Ghanaian senior high school context, where WAEC Chief Examiners repeatedly criticise weak synonym usage and limited word choice (WAEC, 2025), the scarcity of targeted research on standalone or integrated online dictionaries represents a notable gap that the present study seeks to address.

2.3.3 Digital Game-Based Multimedia Technologies

Game-based and multimedia approaches have shown particular promise. Chen et al. (2019) evaluated a mobile game-based English vocabulary learning application among Taiwanese EFL learners and found positive effects on both perceptions and performance, attributing success to gamification elements (points, levels, rewards) that promoted sustained motivation

and retention. Barjesteh et al. (2022) demonstrated that visual vocabulary learning applications helped maintain vocabulary development during emergency remote teaching, with multimedia elements mitigating some negative impacts of disrupted classroom instruction.

Kayra (2024) reinforced these findings by showing that gamified mobile applications created higher engagement than traditional methods. Critically, however, many game-based studies (including Chen et al., 2019) rely on short-term interventions and culturally specific contexts (e.g., East Asia), raising questions about transferability to Ghanaian senior high schools where students may face connectivity issues and varying digital literacy levels. Guo and Li (2022) further caution that individual differences in self-regulation can moderate game-based outcomes, underscoring the need for teacher scaffolding.

Overall, the literature demonstrates consistent benefits across digital applications, dictionaries, and game-based technologies. However, common limitations include small samples, short durations, over-reliance on self-reported data, and insufficient focus on senior high school populations in sub-Saharan Africa. Institutional support, as emphasised by Ewusi-Mensah et al. (2024), emerges as a recurring prerequisite for effective implementation.

2.4. Gaps in the Literature

The reviewed literature demonstrates broad, though not unqualified, support for the effectiveness of digital technologies, particularly mobile applications, game-based tools, and digital reading platforms, in promoting vocabulary acquisition across diverse learner populations (Chen et al., 2019; Guo & Li, 2022; Hao et al., 2021; Lin & Lin, 2019). Theoretical perspectives drawn from Vygotsky (1978), Mayer (2002), and Nation (2001, 2013) provide converging explanations for these benefits, emphasising mediated learning, dual-channel cognitive processing, and the multidimensional nature of word knowledge, respectively. At the same time, the literature consistently cautions that digital tools are not uniformly effective; outcomes depend on pedagogical design, learner characteristics, intervention duration, and the depth versus breadth of vocabulary knowledge being targeted (Schmitt, 2014, 2019; Read, 2019).

Notably, most of the empirical and meta-analytic evidence reviewed originates from Asian, European, and Middle Eastern contexts (e.g., Chen et al., 2019; Guo & Li, 2022; Kurd et al., 2023; Xodabande & Hashemi, 2023), with comparatively few studies examining digital vocabulary acquisition within sub-Saharan African contexts, especially within Ghanaian settings. The available Ghana-focused literature has tended to focus on broader e-learning policy and infrastructure questions (i.e., Ewusi-Mensah et al., 2024) or on bilingual education in under-resourced community schools (i.e., Asante, 2025), rather than on the specific mechanisms through which digital tools support vocabulary acquisition among learners in mainstream Ghanaian basic or second-cycle education. Given persistent concerns about candidates' lexical performance documented in national examination reports (WAEC, 2025), this represents a significant gap in the literature. The present study, thus, seeks to address this gap by investigating how digital technologies can be leveraged for effective vocabulary acquisition within the Ghanaian educational context, by focusing on the SHSs, thereby contributing context-specific empirical evidence to a predominantly non-African evidence base.

Methodology

Introduction

This section presents the methodology adopted for this study. It outlines the research design, population and sample, data collection instruments, data analysis procedures, and ethical considerations. The approach is guided by the study's objectives, research questions, and theoretical frameworks, including Nation's (2013) lexical knowledge framework, Mayer's (2009) Cognitive Theory of Multimedia Learning, and sociocultural perspectives (Vygotsky, 1978). The methodology ensures a systematic and context-sensitive investigation of how

mobile applications, digital dictionaries, and e-learning platforms influence productive vocabulary development among students in the selected cases.

Research Design

This study employs a mixed-methods approach, combining quantitative and qualitative methodologies to yield measurable learning outcomes and contextual insights. The quantitative component employs a quasi-experimental pre-test/post-test design to assess students' improvements in productive vocabulary after their interaction with mobile applications, online dictionaries, and e-learning platforms. The qualitative component utilises semi-structured interviews and questionnaires to examine learners' experiences, perceptions, and challenges in utilising these digital resources. This design aligns with the study's objectives of evaluating tool efficacy, examining the translation of recognition into productive competence, and investigating contextual mediators.

Population, Sample Size and Sampling Techniques

The study was conducted at a Senior High School and a Senior Technical High School in the Ashanti and Bono regions, respectively. The target population consists of students who possess smartphones or digital devices and are familiar with digital learning tools.

A purposive sampling method was employed to select 60 student participants (i.e., 30 from each school) who were pursuing various programmes in the second year of their study. The purposive sampling technique was specifically used to guarantee the inclusion of learners with diverse digital literacy levels, socio-economic origins, and familiarity with digital tools. Participants were divided equally into an experimental group (using digital tools) and a control group (traditional methods) for four weeks.

Data Collection Tools and Analysis Techniques

Data were collected using multiple instruments to ensure a comprehensive assessment of students' vocabulary development and experiences. A pre-test and post-test comprising 50 items on word meaning, collocation, and usage were administered to measure changes in vocabulary knowledge. In addition, a questionnaire containing both Likert-scale and open-ended items was used to gather quantitative and qualitative data on students' perceptions and experiences. To obtain deeper insights into the effectiveness of the intervention, semi-structured interviews were conducted with the experimental group members.

The digital tools utilised in the study included Quizlet, which provided flashcards and game-based learning activities, the Oxford Learner's Dictionary application for vocabulary reference and pronunciation support, and simple e-learning modules delivered through WhatsApp and Google Classroom to facilitate continuous learning and engagement. While the quantitative data were analysed using descriptive statistics and paired t-tests, the qualitative data were analysed using thematic analysis.

Ethical Considerations

This study adhered to ethical standards to ensure the protection of participants' rights and safety. The selected schools granted their approval, and all participants provided informed consent. Also, learners under 18 needed permission from their parents. Again, the participants were informed that they could withdraw at any time without any consequences, and that participation was completely up to them. Using pseudonyms and password-protected data storage helped protect participants' privacy.

The study minimized potential harm by ensuring that evaluation tasks were neither overly challenging nor significantly different from typical classroom activities. Additionally, the participants' responses were documented accurately to uphold intellectual property rights and the integrity of the data collected. These measures ensured that the research was conducted ethically and responsibly, prioritizing the health and safety of all participants while also providing valuable insights into the use of digital technologies and strategies for enhancing vocabulary development.

Analysis of Results

Introduction

The data analysis integrates quantitative and qualitative approaches to evaluate the impact of digital tools on productive vocabulary development among two schools. A sample of 60 participants was stratified into two groups of 30 learners each, based on their primary digital tool usage: mobile applications, online dictionaries, or e-learning platforms.

Results of Quantitative Data

Table 1: Pre- and Post-Test Mean Scores

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain	T-Value	P-Value
Experimental (Digital tools)	23.2 (5.1)	38.5 (4.2)	15.3	9.12	<.001
Control (Traditional)	24.1 (4.7)	30.2 (5.5)	6.1	4.28	<.01

Source: Field data (2026)

Note: Paired *t*-tests conducted; differences statistically significant.

From Table 1, it is evident that both groups began at similar levels (Experimental 23.2, Control 24.1). This confirms a fair starting comparison. After the intervention, the Experimental Group increased to 38.5, a gain of 15.3 points, but the Control Group rose only to 30.2, a gain of 6.1 points. Both improvements were statistically significant ($p < .001$ and $p < .01$), but the Experimental Group's gain was more than double the Control Group's gain. This statistically significant difference demonstrates that digital tools produced a considerably greater improvement in vocabulary acquisition than traditional teaching methods, even though traditional instruction still yielded meaningful progress.

Table 2: Students' Perceptions of Digital Tools (Experimental Group, $n=30$)

Statement	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree	Strongly Disagree (%)
Digital tool improved my vocabulary retention	50.0	40.0	6.7	3.3	0.0
Gamification made learning motivating	46.7	36.7	13.3	3.3	0.0
Instant feedback was helpful	56.7	33.3	10.0	0.0	0.0
Internet issues affected usage	23.3	36.7	26.7	10.0	3.3

Source: Field data (2026)

According to Table 2, most students responded positively toward digital tools, with 90.0 percent agreeing that retention improved and 90.0 percent agreeing that instant feedback was helpful, so instant feedback drew zero disagreement. Gamification was also well received, with 83.4 percent agreement, though slightly more students remained neutral. Internet issues stood apart, with only 60.0 percent agreeing they were a problem and 26.7 percent neutral. Overall, students viewed digital tools favourably, especially for retention and feedback, but connectivity concerns suggest technical infrastructure may still limit consistent and reliable use of these tools in practice.

Results of Qualitative Data

Thematic analysis, as defined by Braun and Clarke (2006) in their six-phase framework, was utilized to examine the open-ended responses from the questionnaire and transcripts derived from eight semi-structured interviews conducted with participants in the experimental group. This analytical procedure encompassed several stages: becoming acquainted with the

data, formulating initial codes, identifying themes, defining and naming them, and ultimately compiling a comprehensive report. Three overarching positive themes and two challenge-related themes emerged, providing rich insights into the student participants' lived experiences with digital tools.

4.3.1 Positive Theme 1: Enhanced Motivation and Engagement

Students frequently described digital tools as transforming vocabulary learning from a tedious task into an enjoyable activity. Features associated with gamification, such as points, levels, and badges within Quizlet, received particular acclaim. One student noted, "The points and leaderboards made me want to keep practicing even after school hours". Responses: Numerous students indicated that the competitive and rewarding aspects mitigated the boredom typically linked to a conventional word list. This theme aligns with the motivational benefits reported in game-based studies (Chen et al., 2019; Kayra, 2024) and suggests that digital tools can address the low engagement often observed in senior high school English lessons.

4.3.2 Positive Theme 2: Digital Tools as Facilitators of Vocabulary Retention

The participants noted that using spaced repetition, audio pronunciation, and contextual example sentences helped them remember new words better. For example, a participant stated, "I can recall words for a longer time because the application shows them again after some days and gives sentences to practice with" (Interviewee 7). Another student shared, "Listening to the pronunciation and seeing pictures helps me remember the meaning" (Questionnaire response, Adventist SHS). These remarks show that multimedia features and the personalised approach of the tools helped students process the information more deeply, which aligns with the findings from Xodabande and Hashemi (2023) and Rezaei et al. (2014). Students also talked about using what they learnt in essay writing and class discussions.

4.3.3 Positive Theme 3: Flexibility and Accessibility of the Mobile Application

The mobile application's portability facilitated learning outside the traditional classroom setting. Numerous participants appreciated the opportunity to study during their free time, in transport, or evenings at home. One interviewee remarked, "I am able to practise vocabulary while waiting for prep or on the way to school" (Interviewee 2). This flexibility was particularly appreciated at one of the schools, which had limited library resources and demanding schedules, fostering incidental and self-directed learning that traditional methods were not able to offer.

4.3.4 Challenge 1: Connectivity and Accessibility Constraints

Internet connectivity, accessibility, school Wi-Fi fluctuation, and limited personal data bundles were the most frequently cited barriers. Several students reported, "The app stops working when the network is bad, so I lose my streak" (Interviewee 5). This challenge was more pronounced with one of the two schools, where connectivity was described as inconsistent, echoing infrastructural concerns raised in Ghanaian studies (Darkoah et al., 2024; Asante, 2025; and Owusu, 2025).

4.3.5 Challenge 2: Digital Distractions and Over-Reliance

Another challenge was digital notifications and multitasking, which occasionally disrupted concentration. One participant admitted, "There are times my mind drifts off to other applications instead of focusing on my studies" (Questionnaire response). Others also admitted to over-reliance on the translation tools, which mostly impede their ability to recall information. This may partially account for the ongoing vocabulary shortcomings frequently noted in the WAEC Chief Examiners' Reports. These challenges underscore the importance of guided use, as emphasized by Guo and Li (2022).

In summary, the qualitative findings enhance the quantitative results, indicating that while digital tools enhance motivation, retention, and flexibility, their effectiveness in Ghanaian senior high schools is contingent upon overcoming contextual obstacles such as connectivity issues and the need for teacher guidance.

Application of the Theoretical Framework to the Findings

The qualitative findings demonstrate strong alignment with the study's theoretical frameworks. The theme of improved retention through interactive and spaced features directly supports Mayer's (2002) Cognitive Theory of Multimedia Learning, as students repeatedly mentioned the benefits of combining audio, visual images, and textual examples, which facilitated dual-channel processing and reduced extraneous cognitive load. This theme also aligns closely with Nation's Lexical Framework (Nation, 2001, 2013). Students' accounts of remembering form (pronunciation and spelling), meaning (associations and concepts), and use (example sentences and collocations) illustrate how digital tools helped develop the multiple aspects of word knowledge. The spaced repetition feature particularly supported Nation's emphasis on repeated encounters and recycling of vocabulary, moving learners from receptive knowledge toward productive use—addressing the limited word range and weak expression often criticised in WAEC reports (WAEC, 2025). The theme of increased motivation and engagement resonates with Vygotsky's (1978) Sociocultural Theory. Gamification and instant feedback provided scaffolding and mediated support within students' zone of proximal development, turning vocabulary learning into a socially and culturally supported activity. Finally, the theme of flexibility and accessibility aligns with the iPAC framework (Kearney et al., 2020). Personalisation (self-paced practice), authenticity (real-world contextual examples), and collaboration (leaderboards and shared progress) enabled students to engage with vocabulary in meaningful ways beyond the classroom. The identified challenges further illuminate the boundaries of these frameworks in Ghanaian senior high school contexts. Connectivity issues disrupted multimedia processing (Mayer, 2002) and the repeated encounters required by the Nation's framework, while distractions highlighted the importance of guided personalisation and scaffolding (Vygotsky, 1978). Overall, the qualitative data not only corroborate the quantitative gains but also validate and extend the theoretical frameworks by demonstrating their relevance and limitations in resource-variable senior high school settings.

Interpretations of Findings

The findings of this study provide clear evidence that digital tools (mobile applications, online dictionaries, and e-learning platforms) have a substantial positive influence on vocabulary acquisition among senior high school students. The experimental group achieved a mean gain of 15.3 points (30.6% improvement) compared to only 6.1 points (12.2% improvement) in the control group. This statistically significant difference ($p < .001$) confirms that the four-week intervention using Quizlet, Oxford Learner's Dictionary, and e-learning modules produced meaningfully better vocabulary retention than traditional methods.

4.5.1 Interpretation in Relation to Research Questions and Theoretical Frameworks

Regarding Research Question 1 (effectiveness on retention), the results strongly indicate that digital tools enhance both the breadth and depth of vocabulary knowledge. From Nation's Lexical Framework (Nation, 2001, 2013), students in the experimental group showed improvement across the three key aspects of word knowledge: form (pronunciation and spelling through audio and visual repetition), meaning (conceptual understanding via pictures and definitions), and use (collocations and contextual application through example sentences). The spaced repetition feature was particularly effective in promoting the repeated encounters Nation considers essential for moving vocabulary from receptive to productive knowledge. This explains the large performance gap between the two groups and directly addresses the limited vocabulary range and weak expression repeatedly criticised in WAEC Chief Examiners' Reports (WAEC, 2025). The findings also align with Mayer's (2002) Cognitive Theory of Multimedia Learning. Students' qualitative comments about remembering words better because they "heard the pronunciation and saw pictures" demonstrate the benefit of dual-channel (visual + verbal) processing, which reduced cognitive overload and facilitated deeper

encoding. This multimedia advantage was absent in the traditional control group, which relied mainly on written wordlists.

In response to Research Question 2 (students' perceptions), over 90% of participants viewed digital tools positively, particularly praising gamification and instant feedback. This supports Vygotsky's (1978) Sociocultural Theory, as the interactive elements and immediate scaffolding helped students learn within their zone of proximal development. Motivation increased because learning became socially engaging (leaderboards) and personally relevant. The iPAC framework (Kearney et al., 2020) is equally evident in the theme of flexibility — students appreciated the personalisation and authenticity of learning vocabulary anywhere and anytime, extending education beyond the classroom walls. Research Question 3 (challenges) revealed important contextual realities. Internet connectivity problems and digital distractions were the two major barriers. These challenges limited the full realisation of the theoretical benefits: poor network disrupted spaced repetition (Nation) and multimedia processing (Mayer), while distractions reduced the quality of scaffolding (Vygotsky) and personalisation (iPAC). This highlights that technological tools alone are insufficient without adequate infrastructure and teacher guidance — a point also emphasised by Darkoah et al. (2024) and Ewusi-Mensah et al. (2024) in the Ghanaian context.

4.5.2 Summary of Interpretations

The integration of quantitative and qualitative data presents a coherent picture: digital tools are highly effective for vocabulary acquisition in Ghanaian senior high schools when properly implemented, but their success is moderated by infrastructural and pedagogical factors. The 15.3-point gain in the experimental group demonstrates that deliberate, technology-mediated practice can meaningfully address the vocabulary deficiencies that contribute to poor WASSCE performance. However, the persistence of connectivity and distraction challenges shows that digital tools should complement, rather than replace, teacher-led instruction.

These findings extend existing literature (Owusu, 2025; Xodabande & Hashemi, 2023; Kayra, 2024; Chen et al., 2019) by providing context-specific evidence from Ghanaian senior high schools. They confirm that when aligned with sound theoretical principles — Nation's comprehensive view of vocabulary knowledge, multimedia learning, sociocultural scaffolding, and mobile learning affordances — digital tools can play a transformative role in language education in resource-variable settings.

Recommendations

The findings of this study have important practical, theoretical, and policy implications. Practically, there is a need to provide teachers at Adventist Senior High School and Twene Amanfo Senior High Technical School with training in the effective use of digital vocabulary-learning tools such as Quizlet and online dictionaries. Improving school internet connectivity and Wi-Fi infrastructure would further enhance students' access to digital learning resources. In addition, students should be guided on the responsible and purposeful use of digital technologies to maximise their educational benefits. From a theoretical perspective, future research should explore the long-term effects of digital tools on vocabulary acquisition across a broader range of Ghanaian senior high schools. Such studies would contribute to a deeper understanding of the sustainability and generalisability of technology-assisted vocabulary learning in English as a Second Language (ESL) contexts. At the policy level, the Ghana Education Service should consider integrating digital vocabulary-learning strategies into teacher education and professional development programmes. Such interventions could help address the persistent weaknesses in vocabulary usage and written expression identified in the West African Examinations Council (WAEC) Chief Examiners' Reports (WAEC, 2025).

Conclusion

This study concludes that the integration of digital tools into vocabulary instruction has the potential to enhance vocabulary learning among senior high school students in Ghana. The findings suggest that the use of such tools can increase learner participation, facilitate vocabulary retention, and contribute to overall language development. Nevertheless, the successful implementation of digital learning approaches is contingent upon several enabling factors, including effective teacher support, adequate technological infrastructure, and sustained learner guidance. Consequently, efforts to strengthen these conditions are likely to improve the effectiveness of vocabulary instruction and support the development of students' language proficiency, thereby helping to address the vocabulary and language expression difficulties frequently reported in national examinations.

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