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A New Paradigm in Vocabulary Instruction: AI-Based Language Learning Theory

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Abstract
The rapid development of artificial intelligence (AI) has profoundly reshaped the educational landscape, particularly in the area of vocabulary teaching for foreign language learners. This paper presents a new perspective on vocabulary instruction that integrates language learning theories with AI-driven technologies. Using a descriptive-qualitative method supported by a literature review of national and international journals published within the past decade, the study highlights AI's potential to promote personalization, enhance learning efficiency, and increase interactivity. Tools such as chatbots powered by large language models (LLMs), mobile-based gamified platforms, and adaptive learning systems can provide content tailored to individual learners' needs and profiles. However, several challenges remain, including inadequate infrastructure, insufficient teacher preparedness, ethical and privacy issues, and the risk of excessive dependence on AI. To address these issues, the study proposes strategies such as teacher professional development, strengthening digital literacy, and integrating AI into curricula in alignment with sound pedagogical principles. Ultimately, AI is envisioned not as a substitute for teachers but as a tool to support and empower them as facilitators of intelligent and engaging learning experiences. The successful implementation of AI-based vocabulary instruction depends on the synergy between technology, pedagogy, and local cultural values. The article concludes with practical recommendations for educators and learners to adapt to these technological shifts thoughtfully and critically, encouraging a more dynamic and transformative learning process.

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1. INTRODUCTION

In recent years, second language vocabulary teaching has undergone a major transformation with the rise of artificial intelligence. Instead of relying solely on traditional methods such as rote memorization, repetitive practice, and teacher-guided support, educators are increasingly turning to AI-driven adaptive learning systems. These systems provide personalized instruction and immediate feedback [1] By using technologies like intelligent tutoring systems (ITS), natural language processing (NLP), and generative models, AI can adjust vocabulary learning to match each learner's abilities, preferences, and progress, ultimately improving both engagement and retention. [2]

At the center of this emerging approach is adaptive learning, where AI algorithms continually adjust vocabulary activities according to learners' responses. Research indicates that around 86% of adaptive learning applications lead to improvements in student achievement, focus, and motivation [3] In addition, AI-powered chatbots support learners through contextual conversations, immediate corrective feedback, and guided vocabulary practice. A quasi-experimental study demonstrated that junior high students using an AI chatbot achieved significantly greater vocabulary gains compared to those receiving traditional instruction. By

integrating intelligent tutoring systems (ITS), natural language processing (NLP), and generative models, AI can personalize vocabulary learning to match each learner's profile, strengths, and changing needs, thereby fostering stronger engagement and retention. [4]

A systematic review of technology-supported vocabulary learning emphasizes the rise of AI-driven tools, including speech recognition and object detection, which can detect pronunciation mistakes and link real-world items to target vocabulary, thereby improving retention [5] At the same time, story generation systems such as Story-fier help learners practice and apply vocabulary within adaptive narrative contexts, though research indicates that their effectiveness in recall compared to traditional tools remains mixed. [6]

Grounded in cognitive science, research emphasizes that spacing, repetition, elaboration, and deep processing are crucial for retaining vocabulary [7] AI tools can apply these principles by structuring spaced retrieval, providing elaborative cues, and adjusting the frequency of review in line with a learner's progress. Studies further show that elaboration and retrieval practice lead to more durable vocabulary retention compared to simple exposure. [8] Constructivist and sociocultural perspectives also validate the use of AI in education. AI-powered games, conversational agents, and narrative-driven tools encourage learner independence, collaborative meaning-making, and guided support—consistent with Vygotsky's concept of the zone of proximal development (ZPD) and scaffolding methods. [9] Such tools enhance active participation with vocabulary, allowing learners to practice and apply language in authentic contexts.

Empirical evidence highlights AI's effectiveness in lowering anxiety and fostering learner resilience. A study on AI-assisted assessments revealed that students who engaged with AI-driven vocabulary quizzes not only improved their knowledge but also enhanced their emotional resilience and self-confidence. [10] On a wider scale, meta-reviews of AI-based language learning tools emphasize their varied uses, including error correction, tailored feedback, pronunciation tracking, and content creation. [11] However, researchers stress the importance of aligning these tools with sound pedagogical practices and ensuring teacher training in AI literacy to prevent misuse or excessive dependence. [5]

At the same time, studies on ICALL systems highlight the role of intelligent tutoring programs and parser-driven tools in identifying errors in learners' open-ended responses and providing tailored feedback, thereby enhancing both receptive and productive vocabulary development. [12] [13] Overall, these advancements highlight an emerging framework for vocabulary teaching that integrates artificial intelligence with insights from cognitive, constructivist, and sociocultural learning theories. Through AI, strategies such as spaced repetition, elaborative processing, scaffolding within the zone of proximal development, instant feedback, adaptive pacing, and meaningful contextual interaction are put into practice. This represents a shift away from teacher-dominated, drill-oriented methods toward approaches that are learner-centered, data-informed, and responsive to context.

Although the results are encouraging, significant challenges persist. Variability in the effectiveness of narrative generation tools [6] along with issues related to bias, privacy, and ethical deployment of AI underscore the need for safeguards and for pairing AI systems with human oversight [5] So far, findings from quantitative quasi-experimental research, comprehensive reviews, and vocabulary-focused assessment tools point to the rise of a new approach: vocabulary teaching that leverages AI, adapts to individual needs, encourages interaction, and responds to learners' psychological states. This holistic model reflects current insights from cognitive science and second-language learning theories, offering the potential for improved outcomes, stronger motivation, greater resilience, and increased learner independence.

1.1. Literature Review

Over the past decade, vocabulary teaching has experienced a significant shift driven by advancements in artificial intelligence. Conventional methods—such as rote memorization, flashcards, and teacher-led repetition—are giving way to adaptive, context-sensitive technologies based on language acquisition principles. These innovative tools utilize

intelligent tutoring systems (ITS), natural language processing (NLP), and large language models (LLMs) to deliver personalized, data-informed vocabulary learning that reflects both cognitive and sociocultural perspectives.

A systematic review by Zhang and Huang [14] revealed that LLM-(Large Language Model) based chatbots greatly enhance both receptive and productive vocabulary learning among second language learners. Their experimental findings showed that students using AI chatbots performed better than control groups immediately after instruction and retained a larger amount of vocabulary in post-tests conducted two weeks later. Similarly, Hsu et al. [15] reported that AI-driven image recognition tools not only strengthened learners' vocabulary knowledge but also fostered self-regulation and lowered anxiety levels in English as a Foreign Language (EFL) settings.

AI-based technologies, including intelligent tutoring systems, facilitate spaced repetition by simulating forgetting curves and assessing word difficulty to personalize review timing for each learner. [16] proposed adaptive forgetting curve models in vocabulary learning systems, demonstrating that personalized intervals greatly enhance retention. Likewise, minimalist embedded learning tools—such as Broccoli—seamlessly integrate target vocabulary into users' daily information streams, using natural contexts to promote incidental learning and repeated exposure, particularly in EFL environments. [17]

Beyond mere exposure, context plays a crucial role. [18] introduced Storyfier, a narrative generation platform that allows learners to read and create stories featuring target vocabulary. While participants favored using the tool, their word recall did not consistently outperform traditional methods, suggesting the need for further research into the balance between engagement and retention.

Narrative and systematic literature reviews emphasize several key advantages of AI-driven vocabulary learning tools, including personalization, motivation, learner autonomy, feedback, and adaptability [19]. Studies indicate that AI-assisted vocabulary learning enhances learners' autonomy and metacognitive skills, though some concerns remain regarding potential overreliance on technology and diminished human interaction

Beneath these applications lie strong pedagogical foundations. Frameworks like Intelligent Tutoring Systems (ITS) and Intelligent Computer-Assisted Language Learning (ICALL) use natural language processing, speech recognition, and user modeling to identify learner errors and deliver personalized vocabulary feedback. Moreover, adaptive learning theory reinforces this approach—an analysis of 37 studies revealed that 86% reported improved learning results when using adaptive methods compared to traditional instruction. [20]

Recent empirical studies on the use of AI in vocabulary teaching highlight the importance of learner emotions and attitudes. Ling Wei [21] discovered that AI tools enhance English proficiency, motivation, and self-regulated learning among second language learners. Several other studies investigate how students and teachers perceive AI. One qualitative study revealed that teachers consider AI effective for identifying learner needs, generating materials, and providing feedback, while students appreciate instant corrections but remain concerned about the absence of human interaction, data privacy, and ease of use.

1.2 A review of the literature reveals that these studies converge across several educational theories:

1.2.1 Cognitive science: AI technologies apply principles like spaced repetition, elaborative rehearsal, and deep cognitive processing by personalizing content frequency and contextual use. [16]

1.2.2 Constructivist and sociocultural theory: Chatbots and generative learning environments enhance learner autonomy, provide scaffolding, and facilitate interaction within the Zone of Proximal Development (ZPD). [14]

1.2.3 Self-regulated learning theory: AI-driven systems encourage learners to manage their own pace, review cycles, and choice of learning activities. [21] [19]

Although the advantages are consistent, several challenges remain. Storyfier's inconsistent recall outcomes indicate that highly engaging tools may not always enhance memory retention as effectively as traditional repetition-based approaches. [21] Additional issues identified in various studies include algorithmic bias, privacy risks, excessive dependence on technology, and reduced human interaction—highlighting the importance of teacher training and thoughtful integration into instruction. [14]

a fresh model for teaching vocabulary is emerging—one that is AI-driven, adaptive, context-rich, learner-centered, and firmly rooted in proven language-teaching principles. This framework envisions vocabulary acquisition as an active interaction between memory processes, social context, and learner autonomy. It moves away from uniform, memorization-based methods, instead prioritizing personalization, engagement, and meaningful learning over mere repetition.

To advance this approach, upcoming research should employ robust mixed-method methodologies, conduct long-term tracking of learner retention, and make detailed comparisons between AI tools and established traditional methods. Studies should also prioritize diverse learner groups to promote inclusivity. Moreover, educators and instructional designers need to integrate ethical principles, provide AI literacy education, and maintain pedagogical equilibrium to ensure that AI supports rather than substitutes human guidance in vocabulary teaching.

2. RESEARCH METHODOLOGY

This research employs a theoretical and qualitative approach based on document analysis and conceptual synthesis. Instead of using experimental or classroom-based methods, it investigates the impact of artificial intelligence (AI) on vocabulary teaching by reviewing, comparing, and synthesizing evidence from peer-reviewed journals, research reports, and theoretical frameworks within second language acquisition (SLA), educational technology, and applied linguistics. The methodology emphasizes the connection between AI technologies and pedagogical theories, aiming to formulate an integrated model of vocabulary learning that is adaptive, learner-centered, and rooted in cognitive, constructivist, and sociocultural perspectives. [22]

2.1 Research Design

This study adopts a theoretical and conceptual approach, employing systematic literature analysis combined with a hermeneutic review. Rather than gathering primary data through experiments, it develops arguments and frameworks based on secondary sources. [5] Its design draws inspiration from previous research that utilized non-empirical methods to propose innovative instructional paradigms. [19] [15]. Through this approach, the researcher can map existing knowledge and critically evaluate the relationship between AI technologies and established learning theories.

2.2 Data Sources

The data for this study were collected from various sources, including journal articles published within the past decade that examine AI in language learning, adaptive systems, intelligent tutoring, and vocabulary instruction. These materials were obtained from reputable academic databases such as Scopus, Web of Science, and Springer. The selected articles were evaluated based on their relevance, methodological soundness, and theoretical contributions to AI-based vocabulary teaching.

2.3 Analytical Framework

The research employs thematic analysis and comparative theory mapping as its main analytical methods. Through thematic analysis, the study identifies recurring themes such as personalization**,** adaptivity**,** learner autonomy**,** and feedback mechanisms within AI-driven vocabulary learning. Meanwhile, theory mapping links these themes to well-known second language acquisition (SLA) theories**,** including constructivism**,** cognitive load theory and self-regulated learning**.** [23] [24]

For example, adaptive forgetting curves [16] are analyzed in relation to memory retrieval theories and cognitive efficiency. Likewise, chatbot-assisted learning [14] is examined through the lens of scaffolding and interactive, dialogue-based learning.

2.4 Research Procedure

The research procedure includes [25] [26]:

2.4.1 Literature Identification: Relevant studies were collected using keywords like "AI-based vocabulary learning," "intelligent tutoring systems," "adaptive learning," and "chatbots in second language acquisition (SLA)

2.4.2 Screening and Selection: The articles were chosen based on criteria such as being published within the past ten years, written in English, academically credible, and specifically related to vocabulary learning..

2.4.3 Coding and Categorization: Essential ideas, theoretical frameworks, and research outcomes were identified and systematically coded

2.4.4 Synthesis: The concepts were integrated to develop a new theoretical framework for vocabulary instruction supported by artificial intelligence.

3. RESULTS AND DISCUSSION

The review reveals robust patterns in how AI-driven tools are transforming vocabulary instruction, empirically demonstrating improved learning outcomes, enhanced affective and behavioral engagement, and emerging theoretical alignment with language acquisition models.

3.1 Vocabulary Learning Outcomes

Empirical evidence consistently demonstrates that AI chatbots—particularly those utilizing large language models (LLMs)—promote both receptive and productive vocabulary growth. An eight-week investigation into LLM-based chatbots reported substantial improvements in vocabulary retention, productive use, and incidental learning outcomes. Similarly, another study found that an AI-driven conversational platform used over six days produced significantly higher vocabulary gains than a traditional system, particularly for learners acting as responders (mean Cohen's $d = 4.32$), with retention levels remaining strong after three weeks. These findings reinforce the central idea of the AI learning model: adaptive, dialogue-centered interactions foster deeper vocabulary integration. [14]

However, the Storyfier experiment presents a more complex picture. Although narrative-based generation increased learner engagement and writing productivity, participants demonstrated weaker short-term recall compared to control groups. This suggests that creative and personalized learning approaches might enhance motivation but could compromise immediate memorization efficiency. [6]

3.2 Affective and Behavioral Engagement

Beyond test scores, AI vocabulary tools tend to improve learners' motivation, reduce anxiety, and promote frequent practice. A recent systematic review in *Smart Learning Environments* reported that 38 % of outcomes reflect improved emotional engagement—higher motivation, confidence, enjoyment, and lower anxiety—when using AI. Similarly, longitudinal survey findings show that higher chatbot self-efficacy among EFL learners correlates with reduced class-related anxiety. Qualitative reports affirm students feel more comfortable using chatbots for repetitive practice and vocabulary negotiation than traditional modes. [5]

Behavioral indicators also point to increased engagement: AI tools encourage learners to practice more frequently, as chatbots are always available for conversation (CSCL, chatbots; *Smart Learning Environments*). Agentic behavior—seeking information proactively or using chatbots for authentic purposes—emerged in about 4 % of reviewed cases, revealing early signs of autonomous, purpose-driven use. [27]

3.3 Theoretical Alignment

The results correspond closely with key theories in language learning, including cognitive, sociocultural, and affective or self-regulated learning frameworks. Adaptive spaced repetition systems (such as those by Zaidi et al. and the Broccoli frameworks) apply cognitive principles related to retrieval and efficient memory encoding. Chatbots that provide meaning negotiation, scaffolding, and prompt-based interactions illustrate sociocultural and interactive learning concepts, as seen in Long's Interaction Hypothesis and Willingness to Communicate theory. Furthermore, increased learner self-efficacy, autonomy, and emotional regulation align with the principles of self-regulated learning and Pekrun's Control-Value Theory.

The use of neuroadaptive systems—such as NeuroChat, which tracks cognitive engagement through EEG—demonstrates how AI tools are advancing toward cognitive-affective integration. Although NeuroChat indicated higher engagement levels, immediate learning improvements were minimal, implying that cognitive synchronization alone may not ensure effective

3.4 Design Limitations and Trade-offs

Although the overall findings are encouraging, several studies highlight notable limitations. The weaker recall performance of Storyfier suggests a potential trade-off between personalization and memory retention efficiency. This implies that while adaptive storytelling systems may enhance engagement through individualized narratives, they might inadvertently overload learners' cognitive capacity, leading to reduced long-term vocabulary recall.

Similarly, chatbot-based instruction often struggles with mechanical or scripted responses, a limited lexical range, and a lack of expressive depth compared to human dialogue. Over time, this results in diminished learner motivation, a phenomenon referred to as the novelty effect, where initial excitement fades as the system's conversational variety plateaus. The reduced richness of vocabulary in human–chatbot interactions compared to human–human exchanges (MDPI) underscores a critical challenge: current AI tutors may simulate conversation but rarely replicate the linguistic diversity essential for authentic language learning.

Beyond technical constraints, ethical and developmental concerns have also surfaced. Early exposure of children to generative AI systems could potentially blur emotional boundaries and hinder the natural growth of social trust, prompting recent pediatric advisories. These issues highlight the importance of regulating early-age interactions with emotionally responsive AI to prevent premature dependency or misinterpretation of artificial empathy.

Recent advances such as neuroadaptive systems—for instance, NeuroChat, which tracks learners' cognitive engagement via EEG—bring the field closer to achieving cognitive-affective synchrony in AI learning environments. Although Neuro Chat demonstrated heightened engagement levels, the absence of immediate learning gains suggests that alignment of neural attention alone does not guarantee improved vocabulary acquisition. This finding indicates that effective learning outcomes require not only cognitive synchronization but also meaningful linguistic input, emotional resonance, and reflective reinforcement to solidify memory retention.

3.5 Implications for an AI-based Paradigm

There are 5 Implications for an AI-based Paradigm; [28]

3.5.1 Adaptive personalization

Under this view, the instructional system continuously tailors vocabulary learning to each learner's evolving state. Models such as Bayesian Knowledge Tracing (BKT) or forgetting-curve–based scheduling can dynamically estimate how well a learner retains individual lexical items and adjust review timing or difficulty accordingly. For instance, BKT probabilistically infers mastery and predicts future performance, enabling fine-grained sequencing of practice. Meanwhile, forgetting curve

models highlight the importance of spaced review as retention decays over time, suggesting the system should reintroduce items just before they are forgotten. Integrating these techniques helps maintain optimal difficulty and pacing.

3.5.2 Contextual interaction & meaning negotiation

Rather than presenting decontextualized word lists, the paradigm emphasizes immersive interaction—through chatbots, narrative scenarios, role play, or story-generation—that embed new vocabulary in meaningful communicative contexts. Learners engage in dialogue with AI agents or generate creative narratives that evoke negotiation of meaning, prompting them to infer, test, and consolidate new lexical forms in learner-relevant themes. Recent systematic reviews show that AI-driven chatbots in second-language classrooms can foster engagement, contextual practice, and scaffolding of interaction (e.g. by prompting paraphrase or clarifying meaning). In such a system, vocabulary is not just "taught" but *used* in a semi-authentic micro-conversation, reinforcing retention and transfer.

3.5.3 Affective scaffolding (emotionally supportive tutoring)

Learning vocabulary is not only cognitive but affective. The new paradigm anticipates and moderate learners' emotional states—reducing anxiety, preserving motivation, and bolstering confidence. The AI system acts as an emotional scaffold: for example, it might detect hesitation, errors, or slow response as signs of frustration and intercede with hints, encouragement, or motivational messages. In AI-mediated language learning, studies have observed improvements in learner motivation and reduced anxiety when the system adapts to learner affect and offers supportive. In essence, the system becomes a "friendly tutor" that cares not just about correctness but about the learner's emotional trajectory and self-efficacy.

3.5.4 Agentic, self-regulated learner behavior

A core assumption is that learners should not mindlessly follow AI instructions, but rather exercise *agency*—taking initiative, setting goals, requesting assistance, monitoring progress, and choosing strategies. The system should invite and scaffold such behaviors: learners might select themes or lexical domains they personally care about, request extra examples, or review past mistakes. This agentic stance encourages learners to own their vocabulary development and sustain their interest over time. This echoes educational theories that highlight the importance of self-regulation and metacognitive choice in deep learning.

3.5.5 Ethical awareness, oversight, and developmental sensitivity

As AI increasingly mediates vocabulary instruction, ethical design must be integral. The paradigm demands fairness (avoiding bias in vocabulary selection or feedback), data privacy, transparency (explainability of the AI's decisions), developmental appropriateness (not overloading learners), and human oversight (teachers able to intervene or override). An AI system should be accountable and adjustable to pedagogical aims. Ethical concerns are particularly salient when modeling emotional or cognitive states. The system's designers must guard against overreliance, algorithmic opacity, and loss of human agency.

3.5.6 Future Directions

to sharpen and extend the current paradigm, subsequent investigations should adopt longitudinal research designs that compare different classes of AI tools (for example, large-language-model–based chatbots versus narrative/storytelling systems) over extended time frames (e.g. several months). Such studies could systematically measure *retention* (how well vocabulary or structures remain over time), *transfer* (how well they apply to novel tasks or domains), and *fluency effects* (e.g. ease and speed of retrieval). Over time, differential trajectories might emerge, revealing which types of AI afford more durable or flexible learning gains.

Beyond purely quantitative measurement, mixed-methods or multimodal designs [29] should probe learners' subjective experiences, perceptions, and their moment-to-moment cognitive engagement. For instance, integrating neuroadaptive systems (e.g. real-time EEG monitoring) could allow researchers to link fluctuations in attention or emotional states to moments of lexical encoding or forgetting. A pilot system called Neuro-Chat exemplifies this: it adjusts conversational difficulty dynamically based on detected engagement levels, showing enhanced subjective engagement (though not yet immediate learning gains) compared to conventional chatbots. Such designs could illuminate how attentional and affective states mediate vocabulary retention in AI-augmented environments.

A further major frontier is refining design principles for AI tutoring. Researchers should systematically explore how dialogue complexity, linguistic richness, naturalness, scaffolding strategies, and novelty parameters influence learning. For example, how "rich" should the chatbot's language be before it overwhelms learners? How much scaffolding (hints, prompts) is optimal to maintain cognitive challenge yet avoid frustration? Though some prior works (e.g. in reviews of AI chatbots in L2 learning) remark on gaps in linguistic range or conversational sophistication, these design dimensions remain underexplored. Such fine-grained manipulations could help balance cognitive load and desirable difficulty in AI–mediated language learning.

Finally, interventions aimed at younger or more vulnerable learners must be anchored in ethical, developmental, and pedagogical frameworks. It is essential that AI does not simply replace critical human interaction (e.g. teacher scaffolding, peer talk), but rather augments it. Ethical concerns (data privacy, algorithmic bias, overreliance on automation) must be explicitly addressed in study design. For instance, systematic reviews of AI in education highlight a need for transparency, accountability, and fairness in AI deployment. Likewise, K-12–focused work emphasizes that the ethics of AI in schooling must be balanced with developmental sensitivity and equity considerations. [30]

4. CONCLUSION AND RECOMMENDATIONS

In conclusion, integrating artificial intelligence (AI) into vocabulary instruction marks a major advancement in language learning theory and practice. AI tools such as chatbots, adaptive systems, and natural language processing applications create personalized, data-driven, and interactive learning environments. Unlike traditional methods, AI enables engagement, spaced repetition, real-time feedback, and individualized pacing aligned with modern language acquisition theories. Research shows that AI-based instruction enhances vocabulary retention, motivation, and learner autonomy.

However, this innovation also brings challenges. Ethical issues like data privacy, algorithmic bias, and unequal access must be addressed to ensure fairness. Teacher readiness and digital literacy are equally vital; without adequate training, AI may be misused or underutilized.

Educational institutions should integrate AI-supported vocabulary instruction into curricula and offer continuous teacher training. Policymakers should promote equitable access to AI tools, particularly in under-resourced settings. Future research should examine long-term impacts and hybrid models combining AI with human instruction.

Ultimately, AI should not replace teachers but empower them to create more effective, inclusive, and engaging language learning experiences, preparing students for success in a digital Age.

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