AI Technologies in Optimizing Language Learning: A View of Vocabulary Acquisition

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Abstract

As educational paradigms shift in the digital era, artificial intelligence (AI) technologies have emerged as pivotal tools in language teaching and learning. However, many educators remain unaware of the significance and components of AI technologies in education. This paper provides an overview of AI in optimizing language learning, particularly vocabulary acquisition, through four main aspects. The first aspect covers how AI aligns with theoretical language foundations, especially in constructivism, reinforcement learning, multisensory learning, and incidental learning. Second, it highlights AI features that facilitate language learning, such as personalized language learning, natural language processing, machine learning, adaptive learning, gamification, and computational thinking, with a specific focus on vocabulary acquisition. Third, three types of AI tools are discussed in facilitating vocabulary learning: asynchronous language learning, synchronous interactive platforms, and language assessment. The final aspect addresses the challenges and limitations of AI capabilities, including data privacy, bias, accessibility, over-reliance on technology, and ethical concerns. This paper underscores the potential of AI to transform vocabulary acquisition, enhancing its accessibility and effectiveness for diverse learner populations, while highlighting the need for collaborative efforts among educators, researchers, and technology developers. Ultimately, it contributes to the ongoing discourse on the role of AI in education, providing insights into best practices and future directions for research and implementation in language learning environments.

Keywords: AI technology, language learning, vocabulary acquisition, educational technology

Introduction

Artificial intelligence (AI) has become an indispensable educational tool in the digital era, profoundly impacting language teaching and learning. This study defines AI technologies as a mix of traditional and generative AIs. It represents a shift from being

strictly programmed by humans to being able to adapt its behavior based on the patterns it learns (Gonzalez-Rodriguez & Hernandez-Carrion, 2018). Currently, the adoption of AI-powered tools in language education introduces innovative and effective methods for language learning. These technologies employ sophisticated algorithms and machine learning approaches to provide personalized and adaptive learning experiences, thereby improving the efficiency and effectiveness of vocabulary instruction (Qin & Zhong, 2024; Wang, 2019; Wei-Xun & Jia-Ying, 2024; Zhang, 2023). Unlike traditional vocabulary instruction methods, which often rely on rote memorization and repetitive practice (Nation, 2013), AI tools provide a more engaging and customized learning experience. While traditional methods have been foundational in language learning for decades, they often fail to address individual learner needs and adapt to diverse learning styles. In contrast, AI technologies offer a dynamic approach to vocabulary acquisition by leveraging data-driven insights to tailor learning experiences to each learner's unique strengths and weaknesses (Schulz et al., 2020).

AI technologies offer a wide range of functions that enhance language learning, including personalized learning, adaptive learning systems, gamification, and computational thinking (Al-Said, 2024; Polyzi & Moussiades, 2023; Wang et al., 2024; Wei-Xun & Jia-Ying, 2024). They also provide both asynchronous and synchronous learning support, as well as assessment tools that promote flexibility, real-time feedback, and improved vocabulary acquisition, along with tracking progress in vocabulary development (Benlaghrissi & Ouahidi, 2023; Dujardin et al., 2021; Feng & Ng, 2024; Kayra, 2024; Yildiz, 2023). Despite these advancements, the integration of AI technologies in education is not without its challenges. AI could be biased, difficult to access, untransparent in terms of privacy, a risk of over-reliance, and unethical (Adeleye et al., 2024; Gao et al., 2024; Goldenthal et al., 2021; Ijaiya & Adeniyi, 2024; Li, 2023; Novikov & Kiseleva, 2024; Osorio et al., 2024; Shrivastav & Hiltz, 2013; Siau & Wang, 2020).

Despite the growing presence of AI technologies in education, many educators remain unaware of their significance, scope, and components (Ahmad et al., 2021). Moreover, educators frequently emphasize sociocultural and technical knowledge of AI rather than application-oriented skills, often acknowledging a deficiency in their comprehension of instructional materials, best practices, examples, and tools pertinent to artificial intelligence. (Lindner & Romeike, 2019). To fill these gaps, this article offers a comprehensive review of AI-assisted language learning, specifically emphasizing vocabulary acquisition. It examines several key areas: 1) the relationship between AI technologies and foundational language theories; 2) the roles and features of AI in educational settings; 3) the various AI applications that support language learning, particularly in vocabulary development; and 4) the current challenges in implementing AI technologies in education.

AI and the Theoretical Foundations of Language Acquisition

Several theories of language learning provide a foundational framework for understanding AI applications in this field. The first theory is constructivism, which

asserts that social co-construction shapes the nature of knowledge acquisition (Phakiti & Paltridge, 2015). Constructivism posits that learners actively construct knowledge through interactions and experiences rather than passively receiving information (Lincoln & Guba, 1985; Peggy, 2023; Schwandt, 1997). AI applications in language learning often align with constructivist principles by promoting personalized and student-centered approaches. These approaches cater to individual learning needs and preferences, thereby increasing engagement and effectiveness (Wang, 2019). Another pertinent theory is reinforcement learning. Reinforcement learning interacts with the environment and adjusts its strategies, making it a flexible tool for educational settings. This adaptability aligns well with the constructivist approach in modern education, where technology plays a crucial role in instructional design and feedback mechanisms (Memarian & Doleck, 2024). AI chatbots utilizing reinforcement learning techniques have shown effectiveness in vocabulary acquisition by providing tailored support. Research shows that chatbots like Dialogflow significantly enhance the acquisition of English for Specific Purposes (ESP) vocabulary (Silitonga et al., 2024). This is due to their well-designed content, which includes synonyms and clear definitions. Additionally, chatbots foster an engaging environment that promotes positive interactions and explicit negotiation of meaning, greatly supporting learners' vocabulary development in a second language (Jia Min, 2024; Silitonga et al., 2024). Another study suggests that AI chatbots reinforce learners to gain both productive and receptive vocabulary knowledge, proving that AI chatbots are beneficial for long-term memory retention (Zhang, 2023).

Third, multisensory learning embedded in AI technologies helps enhance vocabulary acquisition. The vision, hearing, smell, and taste are being explored to enhance educational learning (Klašnja-Milićević et al., 2018). These experiences help learners process and memorize information more effectively (Klašnja-Milićević et al., 2018). Applying this theory to vocabulary teaching underscores the value of accommodating various learning styles and complements AI tools by addressing different preferences, thereby improving learner engagement (Yao & Lee, 2023). It is also found that a multisensory instructional approach improves student vocabulary acquisition and retention (Bahari & Dost Mohammadi, 2023; D'Alesio et al., 2007). AI tools that involve multisensory learning, such as Duolingo, allow audio-visual integration in listening and reading the vocabulary and are further developed to be able to test multisensory skills of the English language such as listening, speaking, reading, and writing (Burstein et al., 2021). The final theory that AI technologies foster language learning is incidental learning. Incidental learning is a form of unintended learning that occurs without the learner's conscious intention to learn (Watkins & Marsick, 1992). To elaborate, the students used AI translation tools without noticing substantial language improvement (Daly, 2023). Indeed, incidental learning, which occurs naturally through everyday activities such as using mobile devices, is facilitated by AI tools. This aligns with Prandi et al. (2023); they developed a specific incidental learning approach by using a mobile application and found that incidental learning is enhanced.

In summary, the associated practices that underpin these theories include: 1) an interactive platform that engages students with AI applications (constructivism); 2) a

helpdesk that scaffolds vocabulary acquisition and engagement (reinforcement); 3) a multisensory resource that engages various senses to enhance the four skills of vocabulary learning (multisensory learning); and 4) unintentional language improvement resulting from the use of AI tools (incidental learning).

AI Features in Vocabulary Enhancement

The first key feature of AI-powered vocabulary tools is the capability to deliver highly personalized learning experiences (Narayanan & Kumaravel, 2024). Machine learning algorithms can analyze extensive data on learners' progress, preferences, and performance to tailor vocabulary exercises to individual needs. For example, adaptive learning platforms such as Quizlet and Memrise utilize AI to adjust the difficulty and content of exercises based on real-time assessments of learners' abilities, ensuring that learners are consistently challenged and engaged. This level of personalization helps maintain motivation and fosters more effective vocabulary acquisition compared to traditional one-size-fits-all approaches such as teaching everyone based on the same materials, methods, or levels of language learning (Wei-Xun & Jia-Ying, 2024). AI-driven language learning apps further enhance personalization by adapting to individual learner needs and providing immediate feedback, which is crucial for effective vocabulary acquisition for self-improvement (Wei-Xun & Jia-Ying, 2024). Additionally, AI chatbots employing machine learning algorithms offer escalating levels of support, aiding learners in understanding and retaining new vocabulary. This personalized approach benefits both receptive and productive vocabulary knowledge. Zhang (2023) compared the chatbot and non-chatbot groups and found that the AI Chabot group acquired both receptive and productive vocabulary knowledge than the non-chatbot group while altogether promoting long-term memory retention (Zhang, 2023). The integration of intelligent learning apps in junior English vocabulary teaching also addresses the limitations of traditional methods. These apps not only facilitate personalized learning experiences but also improve teaching quality and stimulate student interest through the after-class and in-class teaching, attention paid to individual students, the improvement of teaching quality, and the decrease of pressure during teaching (Wang, 2019). Hence, AI technologies offer significant advancements in personalized learning experiences, enhancing vocabulary acquisition through adaptive learning platforms, immediate feedback mechanisms, and intelligent learning apps. These innovations reflect a move towards more individualized and effective educational practices.

Second, AI-powered tools provide features such as Natural Language Processing (NLP) and Machine Learning (ML), which are pivotal technologies in analyzing language patterns and enhancing vocabulary learning. NLP, a subset of artificial intelligence (AI), involves the interpretation, assessment, and translation of human languages by machines. Recent technological advancements have significantly elevated the capabilities of NLP, making it a crucial tool in language learning and communication (Chandrika et al., 2024). By leveraging NLP, AI systems can analyze linguistic patterns, perform tasks such as machine translation and speech recognition, and provide tailored learning experiences. The synergy between NLP and machine

learning further enhances these capabilities, to be more precise. Digital language resources are integral to this synergy, as they provide the data necessary for NLP algorithms to function effectively. Together, NLP and ML revolutionize human-machine communication by enabling applications that understand and generate human language, thus facilitating more efficient and personalized vocabulary learning experiences (Al-Said, 2024). Additionally, NLP techniques, such as sentiment and semantic analysis, are increasingly integrated with ML in recommendation systems. These NLP algorithms improve the accuracy of recommendations by analyzing user preferences derived from textual data. A notable advancement in this area is the knowledge graph embedding for contextual recommendation, which combines knowledge graph representations with contextual understanding to offer more personalized recommendations. This integration highlights how NLP enhances ML-based systems through advanced linguistic analysis and deep learning models, contributing to more effective and individualized vocabulary learning for different vocabulary learning users (Gao et al., 2024). In short, the combined application of machine learning and natural language processing significantly enhances the analysis of language patterns and supports personalized vocabulary learning by leveraging advanced algorithms and rich digital resources.

Third, adaptive learning systems are designed to cater to individual learners' needs to enhance vocabulary learning experiences. For example, an innovative AI-driven adaptive system for English language learning utilizes machine learning and NLP to tailor educational content based on real-time analysis of learners' performance, such as adaptive tests. This system offers targeted feedback and adjusts materials according to each learner's specific needs. The adaptive nature of these AI-based systems enables continuous monitoring and customization of learning paths, significantly enhancing efficiency, motivation, and engagement (Qin & Zhong, 2024). By bridging traditional educational methods with personalized learning approaches, these systems revolutionize language education, making English learning more accessible and effective (Qin & Zhong, 2024). Further supporting the efficacy of adaptive learning systems, a meta-analysis of studies conducted from 2010 to 2022 reveals a medium to large positive impact on cognitive learning outcomes compared to non-adaptive interventions (Wang et al., 2024). The analysis, which reviewed 45 independent research papers, demonstrated that AI-enabled adaptive systems substantially improve student outcomes by addressing cognitive, affective, and behavioral aspects and optimizing navigation and assessment processes (Wang et al., 2024). In the context of vocabulary acquisition, the use of automatic speech recognition as an adaptive vocabulary learning tool could foster the development of speech-based input in students (Wilschut et al., 2024). Therefore, adaptive learning systems powered by AI and NLP offer tailored educational experiences that significantly enhance vocabulary learning and overall educational effectiveness.

Another advantageous feature is the integration of gamification into AI-powered educational apps, which plays a significant role in creating engaging and interactive environments for vocabulary practice. Gamification enhances learner motivation and engagement, which is the key factor in effective vocabulary acquisition in making the

learning process more enjoyable and interactive (Wei-Xun & Jia-Ying, 2024). For instance, the Integrated Gamification-AI Learning Theory (IGALT) demonstrates how gamification can make AI education accessible and captivating for young learners. The "TransAI" platform, featuring a Lego-Transformer-like character, uses interactive missions to teach AI concepts, fostering creativity and foundational understanding in children (Roopaei & Roopaei, 2024). A hybrid gamification framework combining AI, machine learning, and the Adaptive Neuro-Fuzzy Inference System (ANFIS) has also been developed to enhance student motivation and engagement (Narayanan & Kumaravel, 2024). They identified struggling and high achievers so practitioners can adapt assistance and training to enhance student achievement. This framework personalizes learning experiences by analyzing student interactions and providing tailored support, as evidenced by a pilot study with computer science students (Narayanan & Kumaravel, 2024). Further supporting the effectiveness of gamification, an online application incorporating games, quizzes, and chatbots was found to significantly improve vocabulary learning outcomes (Narayanan & Kumaravel, 2024). Students in the experimental group using this application reported better performance than students in the control group studying a vocabulary section from the book, and they found the AI tools both enjoyable and effective compared to traditional methods (Polyzi & Moussiades, 2023). Moreover, research shows that hedonic motivations facilitated by gamified chatbots lead to increased behavioral engagement and purchasing, while utilitarian motivations may have different effects on emotional engagement (Elmashhara et al., 2024). Finally, the integration of AI and gamification into educational systems has gained prominence, particularly in secondary and higher education. This approach aims to improve academic performance by creating engaging and supportive learning environments (Figueroa & Rivera-Loaiza, 2023). AI-driven gamification highly enhances vocabulary learning by making educational experiences more engaging, interactive, and tailored to individual needs, thereby fostering better learning outcomes and increased motivation.

The final advantageous feature is the application of computational thinking, which leverages vocabulary richness to facilitate advanced functions such as speech recognition and generation. Previous research indicates that incorporating computational thinking (CT) in language learning, supported by AI, enhances vocabulary richness in writing (Tang & Ma, 2023). By utilizing CT skills such as data analysis and pattern recognition, learners can improve their vocabulary acquisition efficiency (Tang & Ma, 2023). Specifically, AI technologies that focus on pronunciation education can significantly enhance vocabulary retention. AI-based pronunciation tools assist learners in practicing and refining their pronunciation, which, in turn, supports long-term vocabulary memorization, as found in the study of Kazu and Kuvvetli (2023b), where an ANOVA was used to assess student word retention over four weeks. Between the two teaching methods (phonetic alphabet pronunciation and AI-based speech recognition pronunciation), AI-supported speech recognition significantly improved students' word retention (Kazu & Kuvvetli, 2023a).

Types of AI Applications in Vocabulary Learning

Applications of AI can be categorized based on their functions. First, optimizing vocabulary acquisition through the use of language learning apps asynchronously, as these mobile apps offer flexible and efficient ways for students to learn vocabulary (Kayra, 2024). Asynchronous learning offers flexibility and self-paced exploration (Saxena & Carnewale, 2023); for example, Matlab introduces a new method for reviewing English words, allowing users to customize their lexicon, prioritize words, and practice spelling on an hourly basis rather than the daily basis used by most existing online platforms. This approach has been shown to improve the orthography of target words (Cao, 2024). Studies on mobile dictionary applications have demonstrated their efficacy in enhancing the receptive and productive vocabulary proficiency of English as a Foreign Language (EFL) learners (Dan et al., 2024; Jumabekovna, 2024). The study emphasized that students with higher levels of motivation achieved higher improvements in vocabulary (Dan et al., 2024). In Uzbekistan, where English is used as a foreign language, Jumabekovna (2024) argues that popular language learning apps such as Duolingo, Memrise, Babbel, Rosetta Stone, and Lingodeer are effective for vocabulary enhancement, supported by research studies and testimonials from B2-level students. Additionally, for students below the B2 level, AI apps like Kahoot and Quizlet have been confirmed to effectively improve vocabulary learning in secondary school students compared to conventional teaching methods (Benlaghrissi & Ouahidi, 2023).

The second type of AI applications for promoting vocabulary learning include an interactive AI platform such as chatbots and virtual tutors. This is considered synchronous learning, which promotes real-time engagement and interaction (Saxena & Carnewale, 2023). Previous research has demonstrated that interactive vocabulary practice, particularly through the use of AI chatbots, holds significant potential for automating and enhancing educational tasks (Zhang & Huang, 2024). These chatbots effectively capture the complexity and diversity of human language, thereby significantly aiding students in acquiring both receptive and productive vocabulary knowledge during second language learning (Zhang & Huang, 2024). This finding aligns with another study indicating that chatbots, such as ChatGPT, support learners in mastering word forms, meanings, and usage based on the nation's multidimensional framework of vocabulary knowledge (Yildiz, 2023). In terms of virtual platforms, a study investigating VR-assisted language learning revealed that such technology enhances vocabulary learning and memory retention among EFL learners (Feng & Ng, 2024). The visual, aural, and textual stimuli provided by VR technology help learners subconsciously retain vocabulary items (Feng & Ng, 2024). Additionally, integrating Google Street View into a 3D virtual environment has been found to support both contextualized and motivational vocabulary learning processes in realistic settings (Shih, 2023). Another virtual tool, Wics, an IVR system, was proposed for its ability to offer learners multiple learning sessions and encounters with the same words in varied exposures, thereby providing learners with control over their explorative learning (Bergsma et al., 2023).

The final function of AI applications is their role as assessment tools. AI apps can effectively measure vocabulary knowledge, with research highlighting their ability to assess vocabulary and inform educational strategies (Dujardin et al., 2021). Prior studies have utilized mobile apps for formative assessment purposes (Poláková & Klimova, 2020). These apps enable students to practice vocabulary and receive immediate feedback, facilitating continuous assessment and allowing students to understand their learning outcomes and enhance their vocabulary skills. The accessibility of mobile devices makes them an ideal platform for ongoing vocabulary assessment and learning (Poláková & Klimova, 2020). In order to validate that mobile devices are valid tools in assessing vocabulary assessment and learning, Young et al. (2024) studied Mobile Toolbox (MTB) word meaning and validity evidence from 3 studies by employing over 7,525 participants. Regarding validity and reliability, the Mobile Toolbox (MTB) Word Meaning app has demonstrated adequate to good internal consistency ($\rho xx = 0.78$ to 0.81) and good test-retest reliability (ICC = 0.65) across multiple studies, indicating stable performance over time. It also shows moderate to large correlations with measures of similar constructs ($\rho = 0.67$-0.75), supporting its convergent validity (Young et al., 2024). Additionally, the construct validity of vocabulary assessment tools, such as WordFAM, a web-based platform for evaluating English vocabulary knowledge, has also been confirmed (Drown, 2023).

To conclude, AI applications that expand vocabulary learning can serve as asynchronous language learning apps, virtually synchronous platforms, and assessment tools. Anyhow, the limitations of language learning apps could be predicted, such as the lack of human interaction and feedback, limited range of vocabulary covered in the app, and inability to address individual learning needs (Jumabekovna, 2024). The next section will elaborate on the limitations of AI.

Challenges in Implementing AI Technologies in Vocabulary Learning

Despite the numerous benefits, AI technologies also face challenges. Foremost among these is the issue of data privacy. In some regions, such as the United States, AI technologies face skepticism due to concerns about privacy. Previous studies have indicated that the current legal frameworks in the U.S. are not fully equipped to address the rapid advancements in AI technologies, particularly regarding data collection, anonymization, and consent management. This regulatory gap creates challenges in ensuring privacy compliance while maintaining user convenience (Ijaiya & Adeniyi, 2024). Security issues often confuse privacy concerns, masking the fundamental privacy implications of AI. It is crucial for AI developers to understand these nuances and communicate effectively with users about the privacy impacts of AI systems (Nallam et al., 2024). Developing trustworthy AI systems may be a potential solution, as perceptions of privacy, security, and trust overlap and significantly impact the adoption and use of AI technologies (Leschanowsky et al., 2024). As found in the study of Data Privacy Vocabulary (DPV), it is a framework developed to create machine-readable and interoperable representations for personal data processing. It supports legislative requirements like the EU's General Data Protection Regulation (GDPR) and can be customized for specific use cases (Pandit et al., 2024). The contents,

methodology, current adoptions and uses, and future potential of DPV are in acting as a common vocabulary to support various regulatory (e.g., EU's DGA and AI Act) and community initiatives (e.g., Solid) emerging across the globe (Pandit et al., 2024). The issues of data privacy and vocabulary learning may not directly link to each other. However, privacy can affect how vocabulary is applied to a corpus of GDPR-compliant privacy policies for vocabulary learning further (Leone & Di Caro, 2020).

Another concern is the bias in AI algorithms. According to Li (2023), bias in artificial intelligence systems has the potential to perpetuate discrimination and social inequities, which can have ethical, legal, and social ramifications for organizations. Because artificial intelligence systems frequently learn from past data, which may have preexisting biases in society, this might result in biased outputs. One example of a factor that can lead to gender bias in artificial intelligence applications is the underrepresentation of women in datasets (Chadha 2024). According to Çırtlık and Cosar (2024), it has been discovered that artificial intelligence applications, including chatbots and art generators, have the ability to reinforce gender stereotypes and promote a male-centric perspective. In terms of vocabulary learning, AI systems often learn from large datasets that reflect societal biases. For instance, language models trained on biased corpora can perpetuate stereotypes, such as associating certain professions with specific genders, as seen in translation tasks where gender-neutral sentences are translated with gendered pronouns (Caliskan, 2023). In any case, this issue can be handled by utilizing transparent frameworks. These biases could potentially lead to the accuracy of the obtained information. Anyhow, the solution is suggested; according to Fazil et al. (2024), the establishment of explicit and transparent frameworks for algorithmic decision-making can assist in the identification and reduction of bias.

Ideally, the accessibility of AI technologies could be viewed as inclusive educational practices. For instance, AI, simulation, and e-collaborative tools (AISEC) are being used to improve accessibility in analytics courses in higher education. These tools help address the diverse needs of students with different linguistic backgrounds and analytical skills, promoting interactive engagement and reducing barriers to learning (Osorio et al., 2024). Indeed, AI technologies such as voice recognition, text-to-speech, and AI-powered search systems are enhancing library services for users with disabilities (Kishore et al., 2024). These tools improve accessibility for individuals with visual, auditory, and mobility impairments, making library resources more inclusive (Kishore et al., 2024). Also confirmed by another study is that AI-powered assistive technologies support students with disabilities, enabling full participation in educational activities (Adeleye et al., 2024). Tools like AI-driven captioning and translation improve accessibility for students who are deaf, hard of hearing, or speak different languages (Adeleye et al., 2024). In practice, on the other hand, those accessible tools can be difficult for the less financially supported group of students. Since AI tools are often contingent on the availability of necessary technological infrastructure, such as internet connectivity and compatible devices, demographic factors such as age, education, and income play a crucial role in the accessibility of AI tools. For example, older adults and those with lower educational attainment may face challenges in using AI tools like translation and transcription services (Goldenthal et al., 2021). In terms of

vocabulary learning, inaccessibility arises from various factors: inadequate knowledge and skills to use digital tools effectively, financial constraints that limit technology integration in education (Dahraj et al., 2020), unreliable internet connectivity, lack of guidance on using digital tools properly, and difficulties in understanding complex terminology associated with these tools (Khan & Ayaz, 2023). Collectively, these challenges prevent students from leveraging AI tools for vocabulary development.

Another issue raised is over-reliance on technology. Novikov and Kiseleva (2024) investigated the effects of over-reliance on technology in the foreign language learning process and found that students who were dependent on technology showed less confidence in spontaneous language use. This excessive reliance on technology can hinder students' ability to develop essential language skills (Novikov & Kiseleva, 2024). Moreover, clinging onto the AI tools negatively impacts students' ability to process and construct knowledge (Shrivastav & Hiltz, 2013) and also potentially overlooks critical thinking and problem-solving skills (Grissinger, 2019). This could be seen through the simple act students rely on, such as an auto-correct function in mobile phones or computer software. Indeed, at the vocabulary level, over-reliance on technology can lead to a lack of depth in vocabulary learning. For instance, the Turkish curriculum study highlights that technological tools are underutilized and vocabulary teaching activities remain monotonous, focusing predominantly on reading skills (Mete et al., 2023). In any case, Novikov and Kiseleva (2024) suggest that a balanced approach that integrates technology with traditional teaching methods would be a wise solution to enhance language learning outcomes.

The final challenge in implementing AI technologies in language learning is ethics. Although AI ethics is not directly associated with vocabulary acquisition, it raises significant challenges related to academic integrity and plagiarism within the broader context of language learning in higher education (Perkins, 2023). A roadmap for implementing AI ethically in universities is proposed, focusing on micro, meso, and macro levels to guide stakeholders like SoTL, educational authorities, and policymakers (Castelló-Sirvent et al., 2024). Research says that most participants (77%) were worried about the use of their data; in learning systems, fewer than 8% of adults were ‘not happy’ being tracked, as opposed to nearly two-thirds (63%) of young learners surveyed (Latham & Goltz, 2019). This could lead to urgent calls for a critical examination of how international policies and documents construct ethical standards in AI education (Nemorin, 2024). Since AI technologies seem unavoidable in the current digital era, several ethical aspects are raised, such as privacy and data protection (Gao et al., 2024), fairness and non-discrimination in training data (Siau & Wang, 2020), and accountability and transparency (Gao et al., 2024). Gao et al. (2024) proposed an alternative solution, which involves transitioning from initial ethical considerations to a focus on AI systems that are centered around humans. Additionally, the international organization as well as the database also responded to this issue by providing guidelines for AI ethics, such as Elsevier and UNESCO.

In conclusion, it is crucial to take into account the indirect impacts of data privacy, biases, accessibility, over-reliance on technology, and ethics when

implementing AI technologies for vocabulary acquisition. AI development in language learning is an ongoing development that involves the mutual learning of developers and users to navigate the immediate challenges and to effectively utilize the technology. The following figure illustrates the comprehensive overview of AI technologies for optimizing language learning.

Figure 1

A Comprehensive Overview of AI =Technologies for Optimizing Language Learning

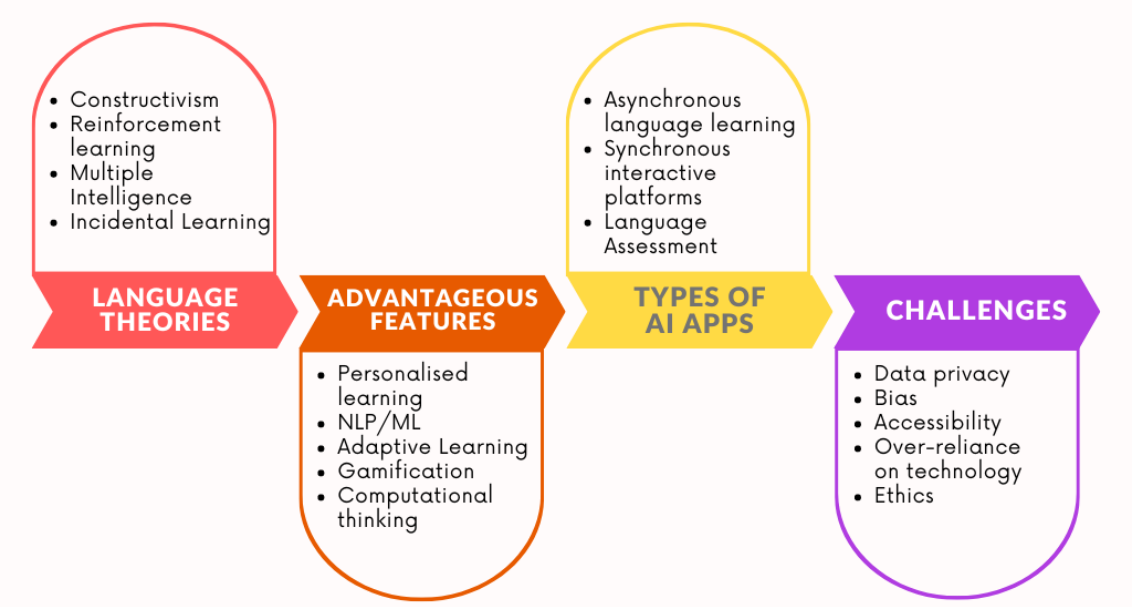

Figure 1 provides a comprehensive overview of AI technologies for optimizing language learning. It illustrates how these technologies enhance vocabulary acquisition by addressing various aspects, including underlying theories, contributing features, types of apps that facilitate learning, and the limitations of applying AI technologies in real-world contexts.

Conclusion

This article provides a comprehensive review of AI-assisted language learning, with a particular focus on the vocabulary aspect. It explores: 1) how AI technologies align with theoretical language foundations; 2) the functions and features of AI in education; 3) the types of AI applications that facilitate language learning, especially vocabulary acquisition; and 4) the current challenges associated with implementing AI technologies. AI-supported language learning can be understood through four main theories: constructivism, reinforcement learning, multisensory learning, and incidental learning. These technologies offer services such as personalized language learning, natural language processing, machine learning, adaptive learning, gamification, and computational thinking, all of which contribute to multi-dimensional language learning. Specifically, vocabulary acquisition can be enhanced through three main types of AI applications: asynchronous language learning, synchronous interactive platforms, and language assessment tools. However, AI technologies in education face several

challenges, including data privacy, bias, accessibility, over-reliance on technology, and ethical concerns.

The teaching and learning implications of using AI technology in language learning, especially for vocabulary acquisition, involve balancing technological tools with traditional teaching methods to enhance learning outcomes (Novikov & Kiseleva, 2024). Further research places an emphasis on integrating AI into educational circumstances (Jia Min, 2024; Yao & Lee, 2024). It is necessary to evaluate the long-term effectiveness of AI-driven vocabulary learning. For example, intelligent tutoring systems and automated writing evaluation tools, which offer interactive and personalized learning experiences, could significantly aid vocabulary acquisition, grammar correction, and pronunciation (Kovalenko & Baranivska, 2024). Additionally, immersive language learning environments, such as virtual classrooms like Wics, may provide additional benefits (Bergsma et al., 2023). As AI technology continues to evolve, it is essential for educators, learners, researchers, and developers to actively engage in this development. Collaborative efforts are crucial to effectively address the emerging challenges and capitalize on the opportunities presented by AI in education. In practice, this paper urges educators to design a dynamic curriculum that harmoniously blends traditional teaching methods with the innovative use of AI. It highlights the necessity of weighing both the benefits and potential pitfalls of AI technologies, including ethical concerns and biases, to ensure a thoughtful approach to classroom teaching and learning.

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