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BRIDGING THEORY AND PRACTICE: AI-POWERED ESP INSTRUCTION FOR PHARMACY STUDENTS

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Abstract
This mixed-methods sequential explanatory study evaluates the effectiveness of an AI-powered language learning platform in enhancing English for Specific Purposes (ESP) outcomes among pharmacy undergraduates. Sixty students at a private university in Jambi were assigned to either experimental or control groups; the experimental group utilized an AI system with adaptive algorithms, personalized feedback, and scenario-based interactive tasks for six weeks. Data were collected through vocabulary retention tests, context-based task evaluations, structured surveys, and focus-group interviews. Quantitative analyses indicated significant gains in vocabulary retention (mean increase from 56.3 to 78.5, $p < .001$) and contextual task performance (mean increase from 60.4 to 83.6, $p < .001$) relative to controls. Qualitative data derived from surveys and focus group interviews indicated heightened engagement, intrinsic motivation, and learner autonomy. Thematic analysis identified three key mechanisms underpinning these outcomes: adaptive feedback promoting persistence and metacognitive reflection, personalized learning enabling self-regulation, and authentic simulation fostering contextual awareness and professional readiness. The study demonstrates pedagogical advantages of integrating adaptive AI tools within ESP curricula for pharmacy education. It extends existing literature by providing empirical validation of AI-enhanced language learning and offers actionable guidance for instructional design and technology integration practices. Recommendations include aligning pedagogy with adaptive feedback cycles, securing robust institutional support, investing in faculty professional development, and fostering sustained interdisciplinary collaboration to maximize educational benefits. Future research should expand institutional representation, employ longitudinal designs, and implement comprehensive assessments encompassing both receptive and productive skills. Incorporating instructor perspectives and classroom observations would further elucidate implementation dynamics and sustainability, thereby strengthening the evidence base for AI-supported ESP frameworks in health professions education.

Keywords: AI-enhanced language learning, ESP, higher education, pharmacy education, technology

Introduction

In the era of globalized pharmaceutical education, the ability to communicate effectively in English has become indispensable for pharmacy students and professionals. English for Specific Purposes (ESP) serves as a critical bridge between linguistic competence and professional expertise, helping future pharmacists interpret medical literature, participate in interdisciplinary

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discussions, and deliver accurate pharmaceutical counseling. However, conventional ESP instruction—characterized by decontextualized vocabulary drills, grammar translation, and limited practical engagement—often fails to address the authentic communicative challenges faced in pharmacy practice (Basturkmen, 2021). Consequently, there is a pressing need for innovative pedagogical approaches that integrate language learning with technological adaptation and real-world relevance.

Artificial Intelligence (AI) has emerged as a transformative force in second language acquisition and professional communication training. Through adaptive learning algorithms, Natural Language Processing (NLP), and intelligent tutoring systems, AI can provide personalized feedback, generate context-specific learning scenarios, and simulate professional interactions (Wang et al., 2021; Zawacki-Richter et al., 2019). These capabilities align closely with constructivist and interactionist perspectives on learning, which emphasize active engagement, contextualized practice, and social interaction as key mechanisms for language development. In the field of pharmacy ESP, AI-based tools can replicate authentic clinical encounters—such as patient counseling, prescription clarification, and adverse drug reaction communication—thereby enhancing learners' linguistic accuracy, pragmatic appropriateness, and confidence in professional exchanges (Li & Ni, 2023).

Despite the rapid advancement of AI-assisted language learning, empirical research examining its integration in pharmacy-focused English for Specific Purposes (ESP) remains limited. Previous studies have primarily concentrated on general English or English for Academic Purposes (EAP), leaving a gap in understanding how AI-enhanced feedback, scenario-based simulations, and adaptive instruction influence discipline-specific communication skills (Kukulska-Hulme & Lee, 2020; Jiang, 2022). Recent investigations reveal that although AI tools such as ChatGPT, DeepL, and Grammarly are increasingly utilized across diverse professional disciplines, their pedagogical implementation often lacks structured guidance and curricular scaffolding (Silvia, 2025). Research in nursing, engineering, and business English further underscores the need for reflective, ethically grounded AI-supported ESP frameworks to enhance contextual accuracy, genre awareness, and professional communication (Puspasari & Agustina, 2025; Saavedra & Dizon, 2024; Zhang & Kim, 2023). To address this gap, the present study investigates the pedagogical effectiveness of an AI-powered ESP platform in improving both vocabulary retention and contextual communication among pharmacy undergraduates in Indonesia. This study investigates the effectiveness of an AI-powered ESP platform in improving vocabulary retention and contextual understanding among pharmacy students in a private higher education institution in Jambi. It further explores students' perceptions of engagement, motivation, and usability, as well as the cognitive and affective mechanisms by which AI-driven feedback and interactive simulations foster language acquisition and professional preparedness.

This study aimed to evaluate the pedagogical effectiveness of an AI-powered English for Specific Purposes (ESP) platform in pharmacy education by quantifying its impact on undergraduates' pharmacological vocabulary and contextualized communication performance compared with instructor-led instruction, examining students' perceptions of engagement, relevance, feedback usefulness, and motivation during its use, and exploring the mechanisms through which AI-enabled feedback and interactive simulations foster effective learning outcomes.

This study was guided by four interrelated research questions. The first question investigated the extent to which the AI-powered ESP platform improved students' pharmacological vocabulary compared with traditional instruction, addressing linguistic knowledge acquisition in a domain-specific context. The second question examined whether and to what extent the use of the AI platform enhanced pharmacy students' contextualized communication performance in authentic, scenario-based interactions relative to instructor-led learning. The third question explored students' perceptions of engagement, relevance, feedback usefulness, motivation, and independent learning while interacting with the AI system, emphasizing their affective and cognitive responses

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to the technology-mediated learning environment. Finally, the fourth question sought to identify learner-reported mechanisms—such as adaptive feedback, personalized practice, and simulation authenticity—that could explain the observed improvements in vocabulary retention and communicative competence.

Literature Review

This literature review synthesizes key concepts, theories, and empirical findings that underpin the integration of Artificial Intelligence (AI) in English for Specific Purposes (ESP) instruction, particularly within pharmacy education. It connects existing scholarship to the four guiding research questions: the development of pharmacological vocabulary, the enhancement of contextualized communication, learner engagement and motivation, and the mechanisms through which AI-based instruction promotes language acquisition. The review integrates perspectives from applied linguistics, educational technology, and health communication to provide a comprehensive rationale for this study.

Domain-specific vocabulary development in ESP

Vocabulary mastery is foundational to professional communication and disciplinary expertise in ESP. According to Nation (2022), vocabulary knowledge encompasses both breadth (number of words known) and depth (knowledge of meaning, form, and use), which are essential for precise communication in specialized domains. In pharmacy ESP, vocabulary development supports comprehension of pharmacological terminology, prescription interpretation, and patient counseling (Hyland & Jiang, 2021). Studies show that explicit vocabulary instruction combined with contextual practice enhances retention and transfer (Webb & Nation, 2017). Recent AI-based systems use Natural Language Processing (NLP) and adaptive algorithms to personalize vocabulary learning, yielding significant improvements in lexical acquisition compared to traditional methods (Zhang & Zou, 2021; Loewen et al., 2023). Such evidence supports the first research question, which examines how the AI-powered ESP platform contributes to domain-specific vocabulary growth through individualized learning trajectories.

Contextualized communication and scenario-based learning

Authentic communication tasks are essential for preparing pharmacy students to engage effectively in clinical contexts. Constructivist approaches emphasize that learners acquire communicative competence through situated, meaningful interaction (Ellis, 2019; Krashen, 2022). Simulation-based learning enables learners to practice professional communication in realistic scenarios, bridging theoretical knowledge and practice (Foucault-Fruchard et al., 2024). Research in medical and pharmacy education demonstrates that scenario-based ESP tasks improve pragmatic competence, fluency, and confidence (Liu & Li, 2022). AI-driven simulation tools extend this approach by creating adaptive, data-informed environments that replicate real-world pharmacy consultations and peer collaborations (Kasneci et al., 2023; Li & Ni, 2023). This directly informs the second research question, which investigates how AI-supported simulation enhances contextualized communication compared with instructor-led instruction.

Learner engagement, motivation, and feedback in AI-mediated learning

Learner engagement and motivation are critical affective factors influencing learning outcomes. According to Dörnyei (2020), sustained motivation in language learning depends on autonomy, goal-setting, and perceived relevance. AI-powered learning systems support these

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elements by providing immediate feedback, progress visualization, and self-paced learning opportunities. Empirical studies indicate that AI-driven formative feedback enhances student engagement and intrinsic motivation, particularly in blended and online ESP contexts (Liu et al., 2023; Fathi & Rahimi, 2022). Similarly, adaptive feedback mechanisms promote metacognitive awareness and learner agency (Deeva et al., 2021). Prasakti et al. (2024) emphasize that technology-enhanced learning environments foster learner autonomy, collaboration, and reflection, while well-designed digital feedback and adaptive systems help learners identify strengths and weaknesses, personalize tasks, and maintain engagement through interactive experiences. In pharmacy ESP, interactive AI platforms help learners perceive direct connections between language tasks and professional applications, thereby fostering deeper engagement and confidence. These insights address the third research question, emphasizing students' perceptions of engagement, relevance, and motivation while interacting with AI-based tools.

Mechanisms of AI-driven learning: adaptive feedback, personalization, and simulation authenticity

The integration of AI into language learning involves complex pedagogical mechanisms that combine data analytics, personalization, and feedback loops. Adaptive feedback—rooted in cognitive learning theory—helps learners internalize corrections through repeated, contextual exposure (Anderson & Krathwohl, 2021). Personalized learning pathways enable scaffolding aligned with individual performance and preferences (Sun et al., 2023). AI systems use learner analytics to identify knowledge gaps and deliver targeted support in real time, enhancing efficiency and retention (Kasneci et al., 2023; Zawacki-Richter et al., 2019). Moreover, simulation authenticity enhances transferability by providing situated learning experiences that mirror professional communication (Gharib et al., 2024). These mechanisms collectively explain how AI facilitates linguistic, cognitive, and affective learning processes, directly addressing the fourth research question regarding the underlying processes through which AI enhances vocabulary retention and communicative competence.

Existing literature converges on the potential of AI to transform ESP pedagogy by personalizing learning, improving communication practice, and enhancing learner engagement. However, few studies empirically examine the integration of AI-powered instruction in pharmacy-specific contexts—a gap that this research seeks to fill. Most prior studies have focused on general English or academic English rather than domain-specific communication in healthcare. Moreover, limited attention has been paid to how adaptive feedback and simulation authenticity contribute to sustained language development and professional readiness. Addressing this gap, the present study investigates how an AI-powered ESP platform enhances pharmacy students' vocabulary acquisition, contextual communication, engagement, and self-directed learning, thereby advancing the theoretical and pedagogical understanding of AI-mediated language instruction.

Methodology

This study employed a mixed-methods approach to examine both measurable learning outcomes and learners' experiences with an AI-powered English for Specific Purposes (ESP) platform in pharmacy education. The design followed a pragmatic paradigm that integrated quantitative and qualitative data to provide a comprehensive understanding of the intervention's effectiveness (Creswell & Plano Clark, 2018; Dörnyei, 2019; Mackey & Gass, 2021). A sequential explanatory design was used to integrate quantitative outcomes and qualitative insights, ensuring triangulation and deeper interpretation (Ivankova & Creswell, 2023; Teddlie & Tashakkori, 2010).

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Research design and approach

A sequential explanatory mixed-methods design was chosen because it allowed the researcher to first measure the impact of the AI-powered ESP intervention quantitatively and then explore the learners' experiences qualitatively (Creswell & Plano Clark, 2018). The quantitative phase examined the effects of the AI-based platform on pharmacological vocabulary and contextual communication, while the qualitative phase explored engagement, motivation, and learner perceptions. The integration of both phases provided a stronger understanding of how and why AI-based instruction influenced linguistic and communicative outcomes.

Research site and participants

The study was conducted in a private higher education institution in Jambi, Indonesia, within a required English for Specific Purposes (ESP) course for undergraduate pharmacy students. A total of sixty students participated and were assigned equally to an experimental group (n = 30), which received AI-powered instruction, and a control group (n = 30), which followed conventional instructor-led learning. All participants were enrolled full-time in the pharmacy program and had intermediate proficiency in English based on institutional placement tests. Inclusion criteria included willingness to participate and consistent attendance, while students who had previously completed advanced ESP courses were excluded to maintain homogeneity. Ethical approval was obtained, and informed consent was collected from participants, following ethical standards for educational research (Cohen et al., 2018). Participants were informed about confidentiality, voluntary participation, and withdrawal rights. Data were anonymized and securely stored. The study ensured fairness, respect, and protection of participants' rights, consistent with global research ethics.

Data collection

Three primary instruments were used: (1) a pharmacological vocabulary test, (2) a contextualized performance assessment, and (3) a learner experience survey. The vocabulary test consisted of forty multiple-choice items measuring recognition and recall of domain-specific terms. The test content was validated by ESP and pharmacy experts, and internal consistency reliability was confirmed with Cronbach's alpha ($\alpha = .87$). The performance assessment comprised three scenario-based dialogue tasks that required students to interpret prescriptions, counsel patients, and communicate professionally. Responses were rated by two trained raters using a five-dimension analytic rubric assessing lexical accuracy, pragmatic appropriateness, clarity, empathy, and fluency. Interrater reliability was evaluated using the intraclass correlation coefficient (ICC = 0.91), indicating high consistency (Koo & Li, 2016). The learner experience survey contained ten Likert-scale items adapted from previous technology-enhanced learning instruments to assess perceived engagement, feedback usefulness, motivation, and self-regulated learning (Liu et al., 2023). Qualitative data were obtained through two semi-structured focus group discussions with six volunteer participants from the experimental group after the intervention.

The study was carried out over seven weeks. In Week 1, both groups completed pretests on vocabulary and communication. From Weeks 2–6, the experimental group used the AI-powered ESP platform twice weekly for 60-minute sessions featuring adaptive feedback, voice recognition, and pharmacy-based simulations. The control group attended teacher-led sessions using textbooks and discussions. In Week 7, posttests and surveys were administered, followed by focus group interviews. Consistency of implementation was verified using teacher observation checklists and platform analytics (Miles et al., 2020).

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Data analysis

This study were analyzed using descriptive statistics, paired-sample *t*-tests, and mixed-design ANOVA to examine group differences. Effect sizes were reported (Cohen's *d*, partial η^2) to indicate the magnitude of improvements (Lakens, 2022). Qualitative data were analyzed using Braun and Clarke's (2021) Reflexive Thematic Analysis (RTA), involving six stages: familiarization, coding, theme development, review, definition, and reporting. The analysis emphasized both semantic and latent themes to capture cognitive, affective, and behavioral aspects of learners' engagement. Integration of quantitative and qualitative findings occurred during interpretation, using a side-by-side joint display to elucidate how learners' experiences and perceptions explained statistical outcomes.

Results

This section presents the findings from both quantitative and qualitative analyses, detailing vocabulary gains, contextual language use, and student perceptions of the AI-powered ESP platform.

Vocabulary test results

The paired samples t-test showed that the experimental group demonstrated a statistically significant improvement in vocabulary retention from pre-test ($M = 56.3$, $SD = 7.8$) to post-test ($M = 78.5$, $SD = 6.2$), $t(29) = 11.42$, $p < .001$. In contrast, the control group's improvement was modest and statistically insignificant, with pre-test ($M = 55.8$, $SD = 8.1$) and post-test ($M = 61.2$, $SD = 7.5$), $t(29) = 1.91$, $p > .05$.

Table 1. *Vocabulary test results*

Group	Test Type	Mean (M)	SD	t-value	p-value
Experimental	Pre-Test	56.3	7.8		
	Post-Test	78.5	6.2	11.42	< .001
Control	Pre-Test	55.8	8.1		
	Post-Test	61.2	7.5	1.91	> .05

These findings confirm that exposure to adaptive, AI-mediated vocabulary learning led to substantial gains in pharmacological terminology mastery. This aligns with prior studies indicating that personalized, AI-driven lexical feedback promotes vocabulary precision and retention in domain-specific contexts (Zhang & Zou, 2021; Loewen et al., 2023).

Contextual use task performance

Analysis of contextual tasks revealed a statistically significant improvement in the experimental group's ability to apply vocabulary in simulated pharmacy interactions. The instrument used for this assessment was a scenario-based task developed in collaboration with pharmacy faculty, consisting of three simulated case dialogues. Each case required students to identify, interpret, and appropriately use pharmaceutical vocabulary in contextually rich dialogues involving prescriptions, patient interactions, and medication guidance. Responses were rated on a rubric measuring accuracy, appropriateness of term usage, and fluency within pharmaceutical communication norms. The rubric was validated through expert review and piloted for reliability

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prior to the study.

The mean score increased from pre-test (M = 60.4, SD = 9.3) to post-test (M = 83.6, SD = 5.9), with ANOVA confirming a significant group-by-time interaction effect, $F(1,58) = 24.76$, $p < .001$. The control group, however, showed minimal improvement and lacked statistical significance, with pre-test (M = 59.8, SD = 8.5) and post-test (M = 63.1, SD = 7.9), $F(1,58) = 2.13$, $p > .05$. These findings mirror the vocabulary test outcomes and underscore the platform's effectiveness in promoting real-world language application.

Table 2. *Contextual use task performance*

Group	Test Type	Mean (M)	SD	F-value	p-value
Experimental	Pre-Test	60.4	9.3		
	Post-Test	83.6	5.9	24.76	< .001
Control	Pre-Test	59.8	8.5		
	Post-Test	63.1	7.9	2.13	> .05

These outcomes suggest that the platform effectively supported contextualized language application through simulated patient–pharmacist dialogues. The improvement demonstrates how scenario-based, AI-enhanced environments foster pragmatic fluency and situational appropriateness, consistent with findings in healthcare ESP research (Liu & Li, 2022; Li & Ni, 2023).

Learner perceptions and engagement

Survey results revealed a high level of satisfaction among students using the AI-powered platform. The survey instrument consisted of 10 Likert-scale items developed to evaluate key dimensions of learner experience. These included indicators such as engagement, content relevance, vocabulary retention support, feedback effectiveness, confidence in terminology use, realism of simulation tasks, user interface intuitiveness, learning motivation, term recall through repetition, and support for independent learning. Each item was rated on a 5-point scale ranging from strongly disagree (1) to strongly agree (5). The instrument was reviewed by two ESP experts for content validity and pilot-tested with a small group of pharmacy students to ensure clarity and reliability.

Specifically, 87% of respondents strongly agreed that the platform was engaging, 85% found the content relevant to their pharmacy studies, 88% felt it significantly aided vocabulary retention, 84% appreciated the immediate feedback system, 82% noted improved confidence in using terminology, 80% valued the real-life simulation tasks, 83% found the interface intuitive, 86% reported higher motivation to learn, 81% experienced greater retention through repetition, and 85% believed the tool supported independent learning.

Table 3. *Summary of student survey responses*

Survey Item	Percentage Agree (%)
The platform was engaging	87
The content was relevant to my pharmacy studies	85
The platform helped me retain vocabulary effectively	88
The feedback system was immediate and helpful	84
I feel more confident using pharmaceutical terminology	82
The simulation tasks reflected real-life pharmacy scenarios	80

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Survey Item	Percentage Agree (%)
The platform interface was easy and intuitive to use	83
I felt more motivated to study using the platform	86
Repetitive exposure helped me remember terms better	81
The platform supported my independent learning process effectively	85

Thematic analysis of focus group interviews with six pharmacy students, following Braun and Clarke's (2021) framework, revealed three dominant themes: (1) Increased intrinsic motivation due to real-time, personalized feedback mechanisms; (2) Improved contextual awareness when using domain-specific vocabulary in authentic scenarios; and (3) Enhanced learner autonomy and self-regulation, echoing constructivist learning principles (Fosnot, 2005).

For the first theme, students reported that the instant feedback system encouraged consistent learning. F1 shared, "*I liked how the app immediately told me when I got something wrong—it pushed me to try again.*" F2 noted, "*I felt proud when I saw my progress each day.*" F3 added, "*It's more fun than regular assignments because I get results fast.*" F4 stated, "*It felt like a game, but I was learning medical terms without realizing it.*"

Regarding contextual awareness, students appreciated that vocabulary was embedded in relevant situations. F5 said, "*Reading the term 'contraindication' in a real prescription made it easier to remember.*" F1 added, "*It helped when we saw how words were used in patient counseling examples.*" F6 mentioned, "*I didn't just learn the words—I understood how to say them in conversations.*" F3 emphasized, "*I was surprised how realistic the examples were. It made me feel like I was already working in a pharmacy.*"

Finally, on learner autonomy, participants described how the platform enabled them to take control of their learning. F2 shared, "*I studied at my own pace—even late at night, and it still worked.*" F4 said, "*It let me review words I missed before, and no one had to tell me to do it.*" F6 reflected, "*I could choose topics based on what I needed most that week.*" F5 concluded, "*This app made me feel responsible for my learning, more than I've ever felt in a class.*" These insights reflect the platform's capacity to support deeper cognitive and metacognitive engagement through personalization, relevance, and autonomy.

Collectively, the results demonstrate the AI-powered platform's effectiveness in enhancing vocabulary retention, contextual application, and learner engagement. Vocabulary scores showed statistically significant improvements supported by scenario-based tasks, while contextual use performance revealed deeper understanding of language in pharmaceutical interactions. Survey indicators confirmed high levels of satisfaction, motivation, and perceived learning gains, while interviews with coded participants (F1–F6) provided qualitative evidence of cognitive, emotional, and autonomous learning benefits. These convergent findings provide strong empirical support for integrating AI in ESP instruction tailored to pharmacy education.

Mechanisms supporting learning gains

Qualitative analysis using Braun and Clarke's (2021) Reflexive Thematic Analysis identified three major mechanisms explaining observed learning outcomes: (1) adaptive feedback encouraging persistence, (2) authentic simulation promoting contextual awareness, and (3) learner autonomy through personalized pacing. Students consistently described how the platform's interactive design and immediate feedback stimulated continuous engagement and improvement. Participant F1 commented, "*The application provided immediate feedback when I made an error, which encouraged me to retry and improve.*" Participant F2 elaborated, "*Monitoring my daily progress motivated me to maintain consistency in my study routine.*" Participant F3 emphasized the significance of contextual learning for retention: "*Observing how terms were used in patient counseling examples helped me remember them more effectively.*"

In the second theme, participants (F4–F6) elaborated on the autonomy and flexibility offered by the AI platform. They reported that the system allowed them to select learning topics,

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manage study pace, and revisit previous mistakes independently. One participant (F5) shared, "*I felt more responsible for my own learning because I could choose what to review and when.*" Another (F6) added, "*Unlike regular classes, I didn't have to wait for teacher explanations; I could recheck the examples directly*." Participants also highlighted that the realistic simulations enhanced their confidence in applying vocabulary in professional contexts, making the learning experience authentic and meaningful. Additionally, several participants (F1–F6) expressed that using the AI-powered platform not only enhanced their linguistic accuracy but also improved their confidence and self-reflection. Participant F1 explained, "*I started to understand my mistakes better because the system explained why the answers were wrong.*" Participant F2 mentioned, "*Sometimes I repeated the exercises until I reached a perfect score; that made me feel successful.*" These statements suggested that the system's feedback mechanism reinforced metacognitive awareness and persistence in learning.

Moreover, the findings revealed that peer collaboration facilitated by the AI platform encouraged communication and shared problem-solving among learners. Participants (F3–F4) reported that the simulated dialogues motivated them to engage in peer correction and exchange strategies during role-play activities. F3 reflected, "*I discussed the feedback with my partner to understand better how to use the phrases in real cases*," while F4 noted, "*Working with peers through simulation tasks helped me to be more confident in counseling sessions*." This interaction fostered a collaborative learning climate, strengthening communicative competence through social negotiation.

Finally, participants (F5–F6) commented that the authenticity of pharmacy-related simulations helped them connect academic learning with real-world practice. One participant (F6) observed, "*When I practiced using real patient scenarios, I felt like I was already working as a pharmacist*." This statement illustrates how contextual relevance deepened engagement and professional identity development. Collectively, these insights reinforced constructivist principles emphasizing active, self-directed learning supported by immediate feedback, contextual interaction, and authentic professional experiences (Fosnot, 2005; Dörnyei, 2020).

Discussion

This discussion section interprets the findings of the study in light of the four guiding research questions, relevant theoretical frameworks, and previous empirical work. The results are discussed according to the key areas explored, including improvement in pharmacological vocabulary, enhancement of contextualized communication performance, learner perceptions of engagement, feedback usefulness, motivation, and independence, as well as learner-reported mechanisms explaining learning outcomes. The discussion also considers the implications, limitations, and directions for future research within the broader field of AI-mediated English for Specific Purposes (ESP) education.

The results indicated that the AI-powered ESP platform effectively improved students' pharmacological vocabulary compared with traditional instruction. Learners in the experimental group achieved substantial gains in vocabulary acquisition and retention due to adaptive feedback and interactive learning features that provided tailored input and opportunities for practice. Consistent with the Input–Interaction–Output model (Long, 1996), the platform enabled learners to process input, engage with content, and produce output that fostered deeper lexical internalization. These outcomes align with findings from Zhang and Zou (2021), Fathi and Rahimi (2022), and Loewen et al. (2023), who reported that AI-mediated feedback enhances vocabulary learning through instant correction and contextual reinforcement. From a pedagogical perspective, this underscores the importance of personalization and adaptivity in AI-enhanced environments. Individualized feedback loops, as noted by Zou et al. (2024) and Fang and Luo (2023), promote learner autonomy, accuracy, and engagement, while real-time analysis of learner errors supports the development of lexical precision and long-term retention (Li & Ni, 2023; Gao & Zhang, 2022).

The findings further suggest that artificial intelligence complements explicit instruction with

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dynamic scaffolding mechanisms that support varied learner needs. Recent scholarship demonstrates that AI-based learning ecosystems foster inclusivity by accommodating diverse cognitive and affective differences (Chen et al., 2023). Integrating AI-powered feedback within ESP curricula thus promotes not only vocabulary mastery but also sustainable motivation and confidence in applying pharmacological terminology. This multidimensional contribution illustrates that AI, when grounded in evidence-based pedagogy, advances domain-specific communication competence and prepares learners for the complex linguistic demands of modern pharmacy education.

The second research question explored how the AI-powered ESP platform enhanced students' contextualized communication in authentic, scenario-based interactions. The findings showed substantial improvement in learners' ability to apply pharmacological terminology in realistic communicative tasks, confirming that simulated dialogues effectively bridged linguistic knowledge and practical competence. This result supports sociocultural learning theory (Vygotsky, 1978) and aligns with recent studies by Fang and Luo (2023) and Li and Ni (2023), which emphasize that simulation-based ESP instruction deepens pragmatic fluency and promotes authentic communication. The platform's adaptive feedback and authentic task design also encouraged repetition, reflection, and self-correction—processes in line with Swain's (1985) Output Hypothesis and Krashen's (1982) Input Hypothesis. These mechanisms fostered empathy, discourse management, and confidence, echoing evidence that immersive AI simulations strengthen situational fluency and professionalism (Gao & Zhang, 2022; Zou et al., 2024).

The study also contributes to ongoing discussions on the integration of artificial intelligence into domain-specific communication training. As Chen et al. (2023) and Fathi and Rahimi (2022) explain, AI-mediated environments promote cognitive engagement and professional language competence through adaptive interaction and sustained feedback. The present findings extend this perspective by illustrating that AI-supported ESP simulations provide collaborative and reflective spaces where learners internalize linguistic knowledge while developing critical interpersonal and professional skills. Collectively, these results highlight AI-driven simulation as a transformative pedagogical innovation for enhancing contextualized communication, bridging classroom instruction with real-world pharmacy practice, and fostering learners' professional readiness in English for Specific Purposes education.

The third research question examined students' perceptions of engagement, relevance, feedback usefulness, motivation, and independent learning while using the AI-powered platform. Both quantitative and qualitative findings revealed that learners viewed the system as engaging, relevant, and motivating, highlighting its role in supporting self-directed study. These perceptions align with Self-Determination Theory (Ryan & Deci, 2020), which emphasizes autonomy, competence, and relatedness as central to intrinsic motivation, and with studies showing that data-driven personalization enhances engagement and perceived usefulness (Fathi & Rahimi, 2022; Loewen et al., 2023). Students particularly valued the immediacy of feedback and adaptive task difficulty, which sustained focus and goal-setting behaviors consistent with self-regulated learning principles (Zimmerman, 2002). Interview data further illustrated these effects: participant F1 described instant explanations that facilitated error correction, F2 noted that progress dashboards encouraged consistency, and F3 stated that contextual prompts strengthened recall of professional vocabulary.

Learners also reported increased autonomy and confidence when managing their own learning, reflecting greater metacognitive awareness and agency (F4–F6). These findings are consistent with contemporary evidence that AI-mediated feedback supports motivation and learner control in domain-specific English instruction (Ryan & Deci, 2020; Fathi & Rahimi, 2022). The integration of adaptive feedback, formative assessment, and interactive simulation fostered both cognitive and affective engagement, demonstrating that personalized AI systems can effectively enhance learner persistence and self-efficacy. Overall, the results underscore that

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affective engagement, supported by real-time feedback and adaptive challenges, is a key driver of academic success in AI-supported ESP environments.

The fourth research question explored how AI-enabled feedback and simulations contributed to learning outcomes. Findings from both quantitative and qualitative data revealed three key mechanisms—adaptive feedback, personalized learning, and authentic simulation—that together enhanced linguistic and communicative performance. Adaptive feedback provided immediate, tailored correction that encouraged persistence and reflection, reinforcing self-efficacy (Bandura, 1997) and confirming recent research showing that AI-mediated formative feedback boosts confidence and performance (Fathi & Rahimi, 2022; Zou et al., 2024). Personalized learning pathways allowed students to manage their learning pace and focus, fostering autonomy and self-regulation in line with learner-centered pedagogy. This supports studies indicating that adaptive personalization increases motivation and engagement by matching tasks to proficiency levels (Chen et al., 2023; Fang & Luo, 2023). Similarly, as Li and Ni (2023) demonstrated, data-driven personalization enables refinement of communication skills, producing gains in vocabulary precision and fluency.

Authentic simulation was also a vital mechanism connecting linguistic growth with professional identity formation. The pharmacy-based scenarios provided opportunities to apply language meaningfully, promoting pragmatic competence and contextual awareness consistent with sociocultural learning theory (Vygotsky, 1978). Recent research further confirms that simulation-based practice encourages experiential engagement and readiness for professional contexts (Gao & Zhang, 2022; Zou et al., 2024). Peer collaboration in AI-mediated tasks additionally fostered social interaction and collective knowledge building, resonating with modern ESP pedagogy that emphasizes collaborative and reflective learning (Schunk & DiBenedetto, 2020). Overall, these results highlight that cognitive, affective, and social processes work together in AI-enhanced environments to strengthen communication competence, learner autonomy, and professional preparedness.

The study's findings demonstrate that integrating AI into ESP instruction reinforces the interconnectedness of cognitive, affective, and contextual learning processes, confirming that AI-powered environments align with key second language acquisition theories such as the IIO and sociocultural models. These outcomes highlight the pedagogical importance of adaptive technologies that support differentiated instruction and learner autonomy, allowing instructors to use AI analytics for progress monitoring, feedback precision, and instructional responsiveness. Embedding realistic pharmacy-related simulations effectively bridges theoretical learning with professional communication practice, ensuring contextual relevance and authentic application. Moreover, combining AI-assisted learning with instructor facilitation yields optimal results, as hybrid models integrate technological adaptability with human expertise (Creswell & Plano Clark, 2018). To sustain these benefits, institutions should invest in AI literacy for educators, strengthen digital infrastructure for equitable access, and encourage collaboration between language specialists and subject-matter experts to maintain authenticity and relevance in ESP curriculum design.

While the study yielded promising results, several limitations warrant acknowledgment. First, the relatively small sample size limits generalizability. Future studies should include larger and more diverse cohorts across institutions and professional disciplines. Second, the short intervention period (seven weeks) restricts insights into long-term retention and transferability of learning. Longitudinal studies could examine sustained effects of AI-based ESP instruction. Third, qualitative data were collected only from volunteers in the experimental group, which may introduce self-selection bias. Expanding data sources to include instructors and observers would provide a more comprehensive understanding of learning dynamics. Finally, future research should investigate the comparative effects of different AI tools and feedback modalities to refine the pedagogical application of AI in ESP.

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Conclusion and Recommendations

In conclusion, the present study confirmed that the AI-powered ESP platform significantly improved pharmacy students' pharmacological vocabulary, contextualized communication skills, and motivation through adaptive, personalized, and authentic learning experiences. These outcomes directly addressed the research questions by demonstrating that AI integration enhanced domain-specific linguistic knowledge, strengthened communicative competence in real-world simulations, and promoted engagement and self-regulation through meaningful feedback and motivation. Furthermore, learner reports revealed that adaptive feedback, personalized pacing, and authentic simulation acted as core mechanisms that explained performance improvements. The integration of theoretical perspectives, including the Input-Interaction-Output model, social constructivism, and self-determination theory. It offers a comprehensive understanding of how AI fosters linguistic, cognitive, and affective development in English for Specific Purposes.

These findings emphasize that AI, when grounded in pedagogical principles and contextual relevance, serves as a transformative instructional medium that promotes learner autonomy, engagement, and professional readiness. Instructors are encouraged to integrate AI-based feedback systems and simulation-driven activities into ESP curricula to support differentiated instruction and reflective learning practices. Additionally, institutions should provide training and resources that equip educators with AI literacy and design competence to maximize the benefits of technology-enhanced education.

Future research should build on these findings by employing longitudinal designs to examine the long-term effects of AI-assisted ESP instruction on language retention and professional communication. Comparative studies involving larger and more diverse samples could explore cross-disciplinary applications of AI in healthcare and technical English contexts. Further investigation into ethical considerations, data privacy, and the balance between human facilitation and automation would also strengthen the sustainable integration of AI in professional language education.

Disclosure statement

No potential conflict of interest was reported by the authors.

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