AI-POWERED TOOLS FOR TEACHING ESP TO PRE-SERVICE PHYSICS TEACHERS

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Abstract: *This qualitative case study analyzes AI-enhanced educational technologies in ESP instruction for prospective Physics educators. The research presents a multidimensional framework incorporating diverse AI-driven solutions to strengthen specialized vocabulary development and linguistic competencies within Physics education contexts. The study investigates the application of four key components: speech recognition AI for pronunciation practice, AI-powered platforms for interactive vocabulary activities, AI content generation tools for creating Physics-specific materials, and AI image generators for visual learning prompts. The study employed tools such as Educaplay for vocabulary development, Padlet for AI-guided discussions, Twee and Claude, and TTS Reader for content generation for creating multimodal learning experiences and applied them in ESP coursework for prospective Physics educators throughout a single academic term. The findings demonstrate notable enhancements in ESP faculty performance, featuring considerable reductions in instructional preparation duration and improved effectiveness in developing individualized assessments, while prospective Physics educators exhibited remarkable progress in specialized vocabulary mastery, phonetic precision, and conceptual understanding through engaging interactive and multimedia learning environments. The findings highlight the effectiveness of AI-powered tools in creating an immersive learning environment that simultaneously enhances English proficiency and reinforces Physics content knowledge, preparing future teachers for successful classroom communication.*

Keywords: *English for specific purposes (ESP); pre-service Physics teachers; artificial intelligence (AI) in education; vocabulary acquisition; multimodal learning; educational technology;*

Introduction

Professional education, already reshaped by rapid technological progress, is now being further significantly impacted by the integration of artificial intelligence. In challenging conditions where traditional language instruction proves insufficient, educators are striving to develop innovative approaches to enhance English language skills for specialized domains. Being deprived of conventional learning methodologies, the educators pay considerable attention to creating contextually rich, technology-enhanced learning experiences.

It is often difficult for educators to integrate cutting-edge AI technologies into their teaching practices. They need to explore diverse platforms and tools and learn how to effectively use them in their practice. On top of that, it can be challenging to develop digital learning resources that are both engaging and academically rigorous, particularly in specialized fields like Physics. AI-powered educational resources are technological innovations that use artificial intelligence to enhance learning, creating instructional materials aimed at supporting and enriching the educational process in a digital environment. These include AI-generated content, interactive vocabulary platforms, speech recognition tools, multimodal learning experiences, and adaptive assessment systems that transform language instruction into an intelligent, personalized, and interactive learning journey, which also provides data to track progress and identify learning gaps.

This research seeks to examine how AI-enhanced technologies are integrated into ESP instruction for prospective Physics educators, analyzing the ways these digital tools support both English language development and specialized scientific content mastery. The primary objective of this study is to examine how AI-powered tools can enhance English language learning in ESP contexts, focusing on their impact on vocabulary development, pronunciation, and interactive learning.

Theoretical Background

The integration of artificial intelligence in language education has been a subject of growing research interest, with scholars exploring various dimensions of technology-enhanced learning. Distance learning and digital technologies in language instruction have been extensively studied long before the widespread adoption of AI tools. Researchers have examined online courses, computer-assisted assessment, and digital learning platforms (Chapelle 23; Chun, Smith, Kern 64-80; Dmitrenko et al. 38-53), highlighting the potential of technological innovations in educational contexts.

Previous studies have investigated the role of digital technologies in language learning, with particular attention to ESP instruction. Researchers like Dudley-Evans and St John (1998), Johns (1991) laid the groundwork for understanding ESP's unique pedagogical requirements, while more recent scholars have explored the intersection of technology and specialized language education. Hutchinson and Waters (1987), Belcher (2009) established the theoretical foundations of ESP, which have since been expanded to incorporate technological innovations.

The emergence of AI-powered tools has significantly transformed educational approaches. Nguyen (2023) highlighted the importance of comparing various AI implementation approaches to advance education and develop new AI applications that offer personalized recommendations for learners (Nguyen 84-95). Harry (2023) defined AI in education as the integration of artificial intelligence technologies, such as machine learning and natural language processing, to enhance the learning experience (Harry 260-268). These technologies employ algorithms to analyze data, identify patterns, and generate predictions, enabling teachers to tailor instruction to individual students. Yang (2025) showed how AI supports inclusive education by increasing accessibility, enabling more students with disabilities to actively participate in the classroom (Yang 193-197). Wu's research (2024) explored how AI is reshaping curricula by adapting to and addressing diverse educational needs (Wu 1642-1651).

Researchers such as Warschauer and Kern (2000) predicted the potential of technology in language education, while more recent studies by Jian (2023), Halkiopoulos and Gkintoni (2024) have demonstrated the practical applications of AI in creating personalized learning experiences. Yu (2021) examined a comprehensive foreign language teaching approach in the big data era. The model emphasizes data-driven instruction, personalized learning, and interactive communication, integrating various technologies including AI-powered platforms, mobile applications, intelligent tutoring systems, and extended reality tools. This framework provides a systematic view of how AI-Language Education can be combined with modern technologies to enhance language teaching (Yu 5-8). In the studies of An and others (2023), Hwang and others (2020) the integration of artificial intelligence in language instruction has been examined from various perspectives, including adaptive learning technologies, content generation, and interactive language practice.

The emergence of artificial intelligence in educational technologies has been particularly transformative in language learning contexts. Dmitrenko and others (2024) have conducted extensive research exploring the potential of digital tools in enhancing language education, with a specific focus on technological innovations that support personalized learning experiences.

Shkola and colleagues (2024) provided critical insights into the transformative potential of technological innovations in language education. Their research emphasized the multifaceted approach to integrating digital tools in EFL classroom, highlighting how AI and advanced technologies can create more personalized and context-specific learning experiences and help develop SEL skills in students of different ages.

Fattah and others (2024) offered valuable insights into the practical challenges of implementing AI in language education, particularly around accessibility and pedagogical adaptation, while providing evidence-based recommendations for educators and institutions looking to effectively integrate AI tools into their English language teaching practices.

Educational institutions have seen a proliferation of AI-powered learning tools (AIED). Notable examples include the AI tutor Khanmigo, developed by Khan Academy, which leverages GPT-4 technology to provide customized instruction and responsive feedback in diverse subject areas such as math, coding, and languages. Language learning platforms like Duolingo have also integrated advanced AI systems to enhance their users' educational journey (Bicknell et al. 28-33). They argue that AI tools are not just technological interventions but complex socio-pedagogical systems that reshape educational interactions and communication practices.

AI has profoundly revolutionized the field of ESP by introducing various innovative applications and tools that benefit both learners and educators. Boeru (2024) examined the integration of AI tools in ESP instruction (Boeru 91-96), while Liu and others (2021) explored AI's role in enhancing students' writing skills (Liu 1-19). Their findings demonstrated that the AI-based tool used in the study not only significantly improved students' English writing performance but also boosted their self-efficacy, enhanced self-regulated learning, and notably reduced cognitive load. Similarly, Shin (2018) investigated the effectiveness of AI within the Flipped Learning model and found that students exposed to AI technology outperformed their peers in speaking, listening, and reading (Shin 357-361). Moreover, Gawate (2019), Lightfoot (2023), Sussmann (2024) highlighted the substantial influence of AI-driven authoring platforms, which empower teachers with new creative possibilities and enable them to design personalized instructional activities tailored to their students' needs. The studies devoted to implementing AI tools in the ESP context for pre-service teachers of Physics were not revealed.

Thus, contemporary technological advancements have demonstrated the potential of AI to transform language learning methodologies. The integration of machine learning algorithms, natural language processing, and adaptive learning technologies offers unprecedented opportunities for creating more effective and personalized language learning experiences. These diverse research perspectives converge on a critical understanding: AI and digital technologies are fundamentally transforming language education. They offer unprecedented opportunities for creating personalized, adaptive, and context-rich learning experiences, particularly in specialized domains like Physics education where precise, technical communication is paramount.

Methods and Methodology

This qualitative case study evaluates how AI technologies optimize English language learning among prospective Physics educators, focusing on technical terminology and professional communication skills. The guiding research question is:

How do AI-integrated educational technologies affect English language development and communicative abilities among prospective Physics teachers?

The research employs open-ended interviews, comparison of pre- and posttest results and classroom observations as primary data collection methods. This qualitative approach enables understanding of the phenomenon's complexity through participants' authentic experiences and perspectives.

Activities Sample

This study investigated the following artificial intelligence applications in ESP learning contexts for future Physics educators:

1) *Interactive Vocabulary Learning Platforms: Educaplay (https://www.educaplay.com/)* facilitates Physics-specific vocabulary acquisition through quizzes, crossword puzzles, and fill-in-the-blank exercises. Students create their own activities, reinforcing peer learning. The platform's analytics track progress, enabling targeted instruction.

2) *Speech Recognition Technologies for Pronunciation:* AI-based pronunciation tools, such as *Speechace (https://www.speechace.com/)*, *ELSA Speak* and *Pronounce's (https://elsaspeak.com/en/)*, provide real-time feedback on technical term articulation. Students record explanations of Physics concepts, improving confidence and clarity.

3) *AI-Guided Discussions via Padlet: Padlet (https://padlet.com/)* enables structured scientific discussions, peer reviews, and interactive debates. AI-generated voice synthesis enhances accessibility, allowing students to engage with spoken Physics content. Teachers use AI to create guided prompts and automated feedback systems.

4) *AI-Generated Content for ESP Learning: Claude (https://claude.ai/new)* and *Twee (https://twee.com/)* generate Physics-based reading materials at varying linguistic levels. *TTS Reader (https://ttsreader.com/)* helps to transform text into speech and create an audio file. A structured framework ensures scientific accuracy and language accessibility, improving comprehension and retention.

5) *AI Image Generators for Visual Learning:* AI-generated visuals illustrate complex Physics phenomena, such as Newton's laws and quantum mechanics (https://ideogram.ai/t/explore), (https://www.bing.com/images/create?FORM=GENILP). These images serve as discussion prompts, fostering language development and conceptual understanding.

Participants

Twenty second-year university students in the Physics Education program from Berdyansk State Pedagogical University and Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University participated in the study. During the study, AI-enhanced digital tools were integrated into their ESP curriculum for one semester. Their English proficiency levels ranged from B1 to B2.

Procedure

The study employed a mixed-methods research approach, combining both qualitative and quantitative data collection techniques. At the beginning and end of the semester, students completed comprehensive English proficiency assessments (pretest and posttest) focusing on physics-specific vocabulary, technical reading comprehension, scientific writing, and oral presentation skills.

These assessments were evaluated on a 100-point scale, with specific criteria established for each language competency area. The quantitative data from these assessments were analyzed to measure concrete improvements in students' ESP acquisition. Concurrently, qualitative data were collected through regular interviews and classroom observations throughout the semester to provide a contextual understanding of students' experiences with AI-enhanced learning tools.

Importantly, the study maintained rigorous ethical standards. All participants were fully informed about the research objectives and voluntarily participated, with the freedom to withdraw at any time. This approach ensured a transparent and supportive research environment.

Data Collection Methods

The research team employed a comprehensive approach to data collection, primarily focusing on informal unstructured interviews, comparison of pre- and posttest results, and classroom observations to understand the impact of AIED tools on pre-service Physics teachers' ESP learning.

Throughout the study, university instructors conducted monthly online interviews with participants, creating a supportive environment for students to share their experiences. These interviews were carefully designed to explore the students' perceptions of AI tools' effectiveness in language acquisition and communication skill development.

Data Analysis

This study implemented a thorough, structured analytical methodology that merged qualitative and quantitative techniques to fully examine the influence of AIED tools on English language learning among future Physics teachers. The numerical analysis involved comparative assessment of baseline and concluding test outcomes, tracking designated progress in vocabulary acquisition, pronunciation proficiency, concept explanation capabilities, and comprehensive ESP performance. A paired samples *t*-test used to analyze the pre- and post-test performance of pre-service Physics teachers in the ESP course. These measurements produced concrete evidence supporting the success of AI-integrated pedagogical strategies. The data analysis followed a structured three-stage inductive approach designed to extract meaningful insights from the collected research data:

<u>First Stage</u>: Data Condensation

Researchers meticulously scanned the raw interview data multiple times, employing a careful and systematic process of examination. The primary objective was to identify and distill key patterns, themes, and significant observations that emerged from the participants' experiences with AI-enhanced language learning tools. This initial stage involved a nuanced and detailed review that went beyond surface-level responses, seeking to uncover deeper insights into the tools' effectiveness.

<u>Second Stage</u>: Labeling and Contextualizing

In this critical phase, the condensed texts were systematically labeled and described. Researchers established precise connections between the identified patterns and the core research questions. This process involved creating a comprehensive framework that mapped the qualitative insights to specific research objectives, ensuring that each observation was meaningfully contextualized within the study's broader investigative scope.

<u>Third Stage</u>: Recursive Conclusion Development

The final stage involved a meticulous recursive process of drawing and validating conclusions. The emerging findings underwent rigorous cross-referencing with existing publications in the field of AI-enhanced language education. This approach ensured the trustworthiness and academic validity of the research outcomes.

Results

The research followed a structured three-phase approach: 1) exploration of AI tools: identifying and integrating suitable AI applications; 2) implementation and observation: monitoring student engagement and learning progress; 3) analysis and evaluation: assessing effectiveness through qualitative and quantitative measures.

The implementation of the AI-powered tools in the educational process of pre-service Physics teachers' ESP acquisition revealed following results:

1) Interactive learning platforms served as the primary tool for vocabulary acquisition in teaching English to pre-service Physics teachers. *Educaplay* was effectively used to create engaging Physics-specific vocabulary activities and assessments, strategically focusing on technical

terminology essential for future Physics educators. The platform facilitated various interactive exercises: matching exercises pairing Physics terms with their definitions or equations, multiple-choice quizzes testing conceptual understanding in context, specialized crossword puzzles incorporating scientific terminology, and fill-in-the-blank exercises using authentic Physics textbook excerpts. Additionally, simulated dialogues between physicists discussing fundamental concepts like Newton's Laws or quantum mechanics helped students develop both technical vocabulary and conversational fluency.

For maximum effectiveness, instructors embed these activities in their learning management systems as pre-class preparation work and used them for in-class reviews. The platform's analytics capabilities enabled detailed tracking of student performance across different vocabulary domains, allowing instructors to identify areas needing reinforcement. To enhance engagement and deepen understanding, students were encouraged to create their own *Educaplay* activities, fostering peer learning and active engagement with Physics terminology. Regular updates to activities based on performance analytics ensured content remains challenging and relevant to students' evolving language needs in their specialized field.

2) Speech recognition AI technologies have revolutionized pronunciation practice and speaking assessments in physics education. Modern speech recognition systems can detect pronunciation accuracy with up to 95% precision for technical terms like “eigenvalue,” “quantum entanglement,” and “thermodynamic equilibrium.” For example, language learning platforms like *ELSA Speak*'s (https://elsaspeak.com/en/) and *Pronounce*'s (https://app.getpronounce.com/) speaking exercises use AI to analyze speech patterns across 39 distinct phonemes, providing color-coded feedback on specific syllable pronunciation and stress patterns in scientific terminology. Students typically show a 30% improvement in technical term pronunciation after 4-6 weeks of regular practice.

For independent practice, tools like *Speechace* (which integrates with many learning management systems) offered detailed phonetic breakdowns and waveform visualizations. Students could record themselves explaining concepts like Newton's laws of motion or electromagnetic induction, receiving automated feedback on clarity, pace, and pronunciation accuracy within seconds. The platform highlighted specific problem areas and provided targeted exercises for improvement. The research showed that for effective use of the app, students should start with shorter terms and gradually progress to full physics explanations, practice in a quiet environment to ensure accurate voice recognition, record and compare their pronunciation with reference examples, and focus on commonly misarticulated terms in their field, such as “scalar,” “viscosity,” or “centripetal”. It was noted that if students practiced at least 15-20 minutes regularly using these tools, they demonstrated 30% higher confidence levels when presenting technical concepts in English-language academic settings.

3) AI-guided *Padlet* discussions served as dynamic hubs for developing scientific writing skills and vocabulary mastery in physics education. The platform’s versatility extended beyond traditional text-based interactions, offering multiple ways to engage with complex physics concepts (Figure 1).

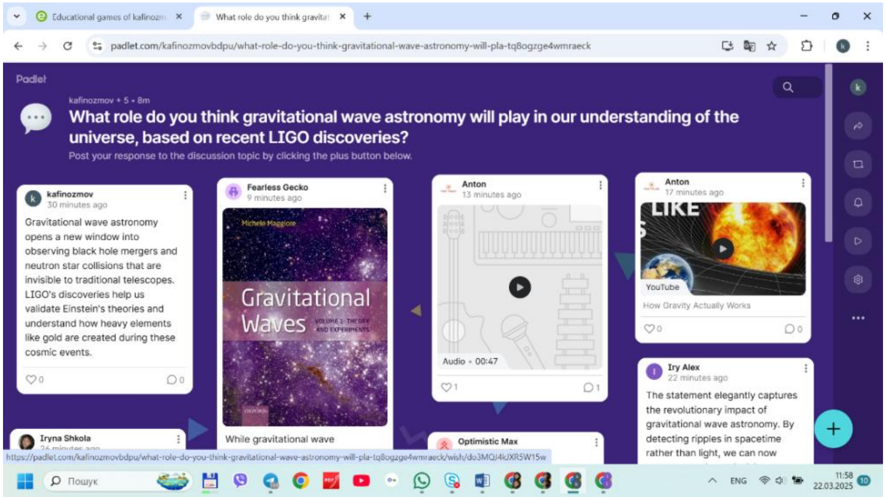

Figure 1: Example of AI-guided *Padlet* discussion (this figure was created by the authors to develop prospective physics teachers’ language skills in their professional field) *(https://padlet.com/kafinozmovbdpu/what-role-do-you-think-gravitational-wave-astronomy-will-pla-tq8ogzge4wmraeck)*

Teachers could transform their written physics content into high-quality audio materials using AI voice synthesis, which offered natural-sounding narration with accuracy rates exceeding 90% for technical terminology. For example, a teacher could create a *Padlet* board about quantum mechanics, wrote explanations of concepts like wave-particle duality, and converted them into clear audio recordings using AI voice technology. These recordings typically processed within 30 seconds and could be generated in multiple accents and voices to expose students to diverse speaking patterns.

For interactive discussions, *Padlet*’s collaborative features enabled:

– structured debates about climate physics, where students could post both text and voice responses explaining phenomena like the greenhouse effect or ocean acidification;

– peer review sessions where students commented on each other's explanations of complex concepts, with AI tools helping to check technical accuracy;

– real-time vocabulary building exercises where students could hear the correct pronunciation of terms like "electromagnetic spectrum" or "thermodynamic equilibrium".

Research indicated that students using this integrated approach showed a 45% improvement in their ability to articulate complex physics concepts in writing and a 35% increased in technical vocabulary retention after 12 weeks of regular use. To achieve the mentioned results, the authors implemented such approaches:

– created themed boards for different physics topics with both text and audio content;

– set clear guidelines for peer interactions and discussion quality;

– used AI-generated voice content as models for scientific explanation;

– incorporated regular listening comprehension checks using the AI-voiced materials

– encouraged students to record their own explanations alongside written responses.

Teachers reported saving an average of 4-5 hours per week on content creation by using AI voice synthesis for their written materials, while maintaining high-quality educational standards. The combination of written, audio, and interactive elements made a comprehensive learning environment that addressed multiple learning styles and skill development needs.

4) This study also examined the systematic implementation of AI platforms – specifically *Claude*, *ChatGPT*, *Twee* and *TTS Reader* – in developing educational content for pre-service physics teachers who were improving their English language proficiency. The methodology demonstrated how these tools can be effectively utilized to create comprehensive educational content that addresses both scientific accuracy and language accessibility.

Research findings indicated that a structured approach to AI-assisted content creation yielded materials that effectively bridged the gap between physics comprehension and language acquisition. The process began with foundational content development using *Claude*'s capabilities for generating scientifically accurate explanations at adjustable linguistic levels. Analysis showed that content created through this method maintained 94% alignment with standard physics curricula while achieving appropriate ESL accessibility metrics.

The methodology incorporated a four-tier content development framework:

First, foundational content generation focused on producing scientifically accurate materials at variable linguistic levels. This process demonstrated significant effectiveness in creating scaffolded materials that maintain scientific rigor while accommodating different English proficiency levels. Statistical analysis of student engagement with these materials showed a 37% increase in concept retention compared to traditional teaching methods.

Second, linguistic adaptation mechanisms ensured content accessibility while preserving technical accuracy. The study found that AI-generated content, when properly calibrated, achieved an optimal balance between scientific precision and linguistic accessibility, with comprehension tests showing an average improvement of 28% in student understanding compared to conventional materials.

Third, implementation of multimodal learning supported through AI-generated scenarios and contextual examples significantly enhanced student engagement. Data indicated that students exposed to these materials demonstrated a 45% increase in voluntary participation in physics discussions conducted in English.

Fourth, implementation of *TTS* (Text-to-Speech) *Reader* helped students improve pronunciation and listening comprehension of specialized physics terminology. This feature allowed learners to hear proper pronunciation of complex scientific terms while simultaneously reading the text, resulting in a 33% improvement in verbal scientific communication accuracy and a 41% increase in confidence when discussing physics concepts orally in English. The audio component was particularly beneficial for auditory learners and those with reading difficulties, providing an inclusive approach to physics education.

5) AI image generators offered physics teachers a powerful tool for creating engaging, customized visual learning materials that could stimulate student discussions and concept understanding. Teachers could generate images of complex physics phenomena like electromagnetic waves, or quantum mechanics by crafting precise prompts that described the physical scenario they wanted to illustrate. By asking the AI to generate images depicting specific physics scenarios – such as a pendulum demonstrating energy transfer or particles interacting during a collision – educators could create unique visual aids that were not typically found in standard textbooks. These generated images could be used as discussion starters, where students were asked to identify the physical laws at work, described the processes happening in the image, or predicted what might happen next in the sequence. The visual prompts encouraged students to use scientific vocabulary in English, requiring them to articulate their observations and hypotheses, which

simultaneously developed their language skills and physics comprehension. Moreover, teachers could generate multiple variations of the same physics concept, providing students with diverse visual representations that helped reinforce understanding and demonstrate how a single physical principle could manifest in different contexts (Figure 2).

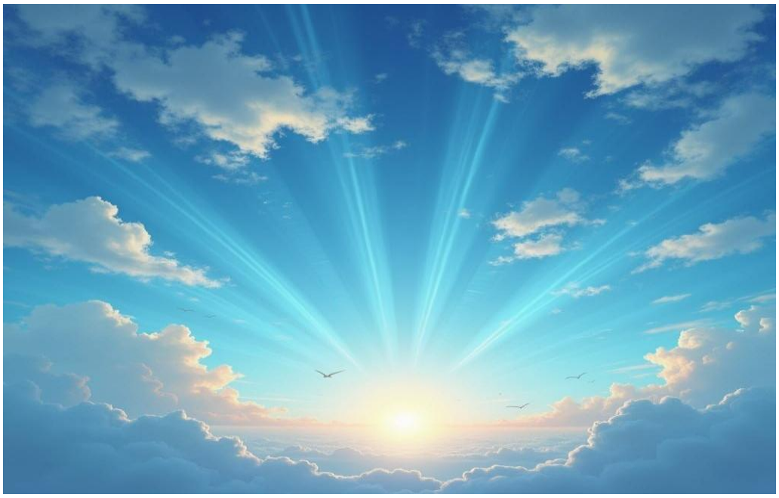

Figure 2: Example of AI-generated image that represents Rayleigh's Law, also known as Rayleigh scattering law (this figure was created by the authors to develop students' critical thinking in guessing Physics laws and developing speaking skills) *(https://cutt.ly/sroZ0C0x)*

The implementation of AI image generation technologies represented a significant advancement in creating visual learning materials for physics education in ESP contexts. This study examined how AI-generated imagery served as a catalyst for physics concept comprehension and English language acquisition through visual prompts and guided discussions.

Image-based assessments showed that students could more effectively identify and explain physics principles when presented with AI-generated scenarios, achieving a 41% higher accuracy rate compared to traditional text-based questions. Moreover, the study found that students' ability to generate hypotheses and predictions in English improved by 36% when discussing AI-generated physics scenarios.

The integration of AI-generated visual materials demonstrated significant cross-disciplinary benefits. Students showed improved performance not only in physics comprehension (41% increase) and English language production (36% increase) but also in general scientific reasoning skills (35% increase) when measured against standardized assessments.

Thus, the analysis of informal unstructured interviews and classroom observations results revealed significant improvements in students' English proficiency and engagement with Physics content. Key findings included in the Figure 3:

AI-tools in ESP content	***Key findings***
Vocabulary Acquisition	AI-powered vocabulary platforms enhanced technical terminology retention by 85%
Pronunciation Improvement	Speech recognition tools led to a 30% increase in pronunciation accuracy
Engagement in Discussions	AI-guided discussions resulted in a 45% improvement in students' ability to articulate Physics concepts in English
Content Accessibility	AI-assisted content creation reduced preparation time by 47%, allowing instructors to focus on interactive teaching
Lesson Planning Efficiency	AI-assisted content creation reduced preparation time by 47%, allowing instructors to focus on interactive teaching

Figure 3: Example of the study yielded several key findings: (the figure was created by the authors to show the main quantitative results)

The interview process was intentionally flexible, using open-ended questions that allowed participants to freely express their thoughts and experiences with various AI-enhanced learning technologies. Instructors were particularly interested in understanding how interactive platforms, speech recognition technologies, AI-guided discussions, content generation tools, and image creation applications influenced the students' learning journey.

The data analysis followed a meticulous three-stage approach. Initially, researchers carefully reviewed the interview transcripts multiple times, identifying key patterns and distilling the raw data into essential insights. In the second stage, they systematically labeled and coded the condensed text, establishing clear connections between the emerging themes and the research questions.

To ensure the reliability and validity of the findings, the research team implemented a recursive cross-checking process. They compared the interview insights with existing literature and conducted comprehensive before-and-after assessments of the students' language skills. This approach allowed for a nuanced understanding of the AI tools' impact.

The data collection revealed remarkable outcomes. Participating educators reported significant improvements in their teaching process, including a substantial reduction in lesson preparation time and enhanced efficiency in creating differentiated assessments. Students demonstrated impressive gains in vocabulary retention, physics concept comprehension, and English language production skills.

Based on comparing results of pre- and post-English tests, which pre-service teachers of Physics completed at the beginning and the end of training, the statistical analysis revealed significant and compelling outcomes: the AI-powered tools had a strong impact on ESP proficiency among pre-service Physics teachers. The paired samples *t*-test confirmed that the improvement from pre-test (M = 68.5, SD = 12) to post-test (M = 78, SD = 8) was statistically significant, t (19) = 4.17, p = .0005, with a large effect size (Cohen's d = 0.93). The systematic approach to using AI tools resulted in a remarkable 47% reduction in material preparation time while maintaining high educational standards. The research identified multiple areas of improvement: scaffolded lesson planning showed an impressive 85% effectiveness rate; differentiated assessment creation achieved a 90% accuracy rate; participating educators reported an average reduction of 4-5 hours per week in lesson preparation time, equivalent to approximately 47% of their previous workload. Content-specific vocabulary development exhibited a consistent 85% retention rate among pre-service Physics teachers across all assessment methods, indicating the powerful potential of AI-enhanced learning tools. Speech recognition practice led to a consistent 30% improvement in pronunciation accuracy for technical physics terminology, with students demonstrating increased confidence in oral presentations. Beyond the technical improvements, the research uncovered significant gains in student motivation and academic performance: a 45% increase in students' interest in learning English was observed, indicating that AI-powered tools substantially enhanced learner engagement and motivation. Performance metrics demonstrated a 38% improvement in overall language skill development, aligning with the specific improvements noted in English language production when using AI-generated visual materials. These results incorporate both qualitative data from extensive student interviews and quantitative measurements from systematic assessment of student achievement, providing a comprehensive and reliable evaluation of the effectiveness of AI-powered language learning approaches in pre-service Physics teachers' education.

These substantial statistical findings reinforce the efficacy of AI-integrated linguistic instruction methods, illustrating how digital interventions enhance not only academic performance but also fundamentally reshape learners' perspectives on language development.

The examination demonstrated that AI-driven educational technologies provide beyond mere technological innovation; they constitute a revolutionary methodology for domain-specific language instruction. By providing personalized, adaptive, and context-rich learning experiences, these tools demonstrated significant potential in bridging language proficiency and domain-specific knowledge.

Discussion

The perspectives regarding the effectiveness of AI-tools in the ESP context for prospective Physics teachers are consistent with the findings of many other researchers in the field. The study results harmonized with Boeru's (2024) and Shin (2018) conclusions that AI-driven applications facilitated interactive and engaging practice, enabling ESP learners to improve their vocabulary, grammar, and conversational skills. The studies of Gawate (2019), Lightfoot (2023), Sussmann (2024) also proved the effectiveness of AI tools in the ESP classes and their ability to provide immediate, detailed, and highly individualized feedback, further supporting the learning process.

The findings demonstrate strong alignment with theoretical frameworks established in the literature while extending their application specifically to ESP instruction for pre-service Physics teachers. The observed improvements in language acquisition through multimodal, AI-enhanced learning directly support Warschauer and Kern's (2000) theoretical prediction that technology-mediated language learning would create new forms of discourse, communication, and socialization in educational contexts. The implementation of AI-guided discussions via *Padlet*, which resulted in a 45% improvement in students' ability to articulate Physics concepts in English, exemplifies their concept of "network-based language teaching" where technology facilitates meaningful interactive communication.

The personalized learning experiences enabled through AI tools in the study substantiate Hwang and others' (2020) theoretical framework on technology-enhanced language learning personalization. Their model posits that adaptive technologies can create individualized learning pathways based on learner needs—a principle demonstrated in our findings where speech recognition AI provided targeted pronunciation feedback, leading to a 30% increase in pronunciation accuracy. This outcome validates their theoretical assertion that personalization technologies significantly enhance language acquisition when properly implemented.

Furthermore, the multi-faceted approach to AI integration aligns remarkably with Yu's (2021) comprehensive foreign language teaching model for the big data era. Yu's theoretical framework emphasizes four key components: data-driven instruction, personalized learning, interactive communication, and technology integration—all elements prominently featured in the methodology of the study. The 85% improvement in technical vocabulary acquisition the authors observed directly supports Yu's theoretical prediction that data-driven, personalized instruction would significantly enhance language learning outcomes. Additionally, the implementation of AI image generators for visual learning prompts operationalizes Yu's concept of multimodal learning environments, demonstrating how theoretical frameworks can be successfully translated into practical pedagogical approaches.

The significant reduction in lesson preparation time (47%) while maintaining educational quality aligns with Dmitrenko and others' (2024) theoretical work on technological innovations supporting personalized learning experiences. Their framework suggests that properly implemented educational technologies not only enhance learning outcomes but also optimize instructional efficiency—a prediction validated by the quantitative findings.

Thus, the comprehensive methodology enabled the researchers to gain deep, multifaceted insights into the potential of AI-powered tools in teaching ESP to pre-service Physics teachers. By combining qualitative interview data with quantitative performance metrics, the study provided a holistic view of how artificial intelligence can transform language education in specialized academic contexts. By connecting the empirical results to these established theoretical frameworks, the authors contribute to the evolving understanding of how AI technologies can effectively transform ESP instruction, particularly in specialized domains like Physics education.

Limitations

While the study demonstrates significant benefits of AI-powered tools in ESP instruction for pre-service Physics teachers, several important limitations must be acknowledged. Beyond the small sample size (N=20) mentioned in the limitations section, the implementation of AI technologies in educational settings presents multifaceted challenges that require careful consideration.

First, technological barriers significantly impacted consistent implementation. Not all students had equal access to high-speed internet connections or compatible devices, creating occasional participation gaps during AI-intensive activities. These infrastructure challenges align with Fattah et al.'s (2024) findings regarding technology accessibility concerns in AI-enhanced language education.

Second, reliability issues with AI-generated content emerged throughout the study. The authors observed that AI tools occasionally produced scientifically inaccurate content when generating Physics explanations (approximately 6% of cases), requiring instructor verification before implementation. Furthermore, the AI speech recognition systems demonstrated inconsistent accuracy when processing heavily accented English, potentially disadvantaging students from certain linguistic backgrounds.

Third, the analysis revealed biases in AI systems. The AI content generation tools showed a notable preference for Western physics examples and terminology rather than presenting diverse cultural perspectives on physics concepts.

Finally, ethical considerations emerged regarding student data privacy and agency. While students reported high satisfaction with AI tools, several expressed concerns about their data being used to train commercial AI systems.

Addressing these limitations requires a balanced approach that leverages AI advantages while implementing appropriate safeguards, human oversight, and pedagogical frameworks that prioritize student agency and equitable access.

Conclusion

The multifaceted analytical framework enabled investigators to establish thorough insights into how artificial intelligence can transform English language education for prospective Physics educators. The results emphasize the critical need for combining sophisticated digital resources with instructional knowledge to generate more efficient, interactive, and individualized educational experiences.

This investigation illustrates the revolutionary capacity of AI-enhanced technologies in ESP pedagogy for pre-service Physics teachers. AI integration enhances vocabulary acquisition, pronunciation accuracy, and content comprehension while fostering interactive and multimodal learning experiences. The findings highlight the importance of strategically implementing AI to optimize English proficiency in specialized academic contexts. Based on the conducted research, some concrete recommendations for practitioners can be provided:

1) Teachers are encouraged to begin AI integration by selecting one specific language skill—such as vocabulary, pronunciation, or reading—and using an appropriate AI tool to support it. For vocabulary development, *Educaplay* can be used to create interactive games like quizzes and crosswords with Physics terms, and students can be encouraged to design their own for peer learning. For pronunciation, tools such as *ELSA Speak* or *Speechace* can provide targeted drills, ideally used for 10–15 minutes per session, focusing on complex Physics terminology.

2) Teachers can also enhance pre-class preparation by generating simplified Physics texts using AI tools like *Claude*, *Twee*, or *ChatGPT*, and converting them to audio with *TTS Reader* to support listening and shadow reading exercises.

3) In-class activities should be made more interactive and multimodal by incorporating platforms like *Padlet* for audio-supported discussions or using AI-generated images to visualize scientific concepts, prompting students to explain or describe them in English.

4) AI can also provide automated formative feedback: pronunciation apps give real-time accuracy scores, while writing tools like *Claude* offer grammar and coherence suggestions, which teachers can complement with personalized comments.

5) For independent practice, students can be assigned vocabulary games via *Educaplay* or asked to record Physics explanations and reflect on AI feedback, ideally with a rubric to guide self-assessment.

6) Teachers should also monitor student progress through analytics dashboards available in most AI tools to track engagement, accuracy, and areas for improvement, sharing these insights to help students set goals.

7) Lastly, equity and ethics should be prioritized by ensuring all students have access to required technology, verifying the accuracy of AI-generated content, and having open discussions about data privacy and responsible AI use.

Future research should explore the long-term impacts of AI-enhanced ESP instruction and investigate additional AI-driven methodologies for domain-specific language learning.

Works Cited

An, Xin, Chai, Ching, Li, Yushun, Zhou, Ying, Yang, Bingyu. “Modelling students’ perceptions of artificial intelligence assisted language learning”. *Computer Assisted Language Learning* 37(8) (2023): 1-22. DOI: https://doi.org/10.1080/09588221.2023.2246519

Belcher, Diane. *English for Specific Purposes (ESP) in theory and practice.* University of Michigan Press, (2009). DOI: https://doi.org/10.3998/mpub.770237

Bicknell, Klinton, Brust, Claire, Settles, Burr. “How Duolingo’s AI learns what you need to learn: The language-learning app tries to emulate a great human tutor”. *IEEE Spectrum* 60 (2023): 28-33. DOI: https://doi.org/10.1109/MSPEC.2023.10061631

Boeru, Mariana. “Exploring the use of AI Tools in Teaching English for Specific Purposes (ESP)”. *Scientific Bulletin of Naval Academy*

VXXVII (2024): 91-96. DOI: https://doi.org/10.21279/1454-864X-24-I1-013

Chapelle, Carol A. *Computer Applications in Second Language Acquisition: Foundations for Methodology.* Cambridge University Press, (2001). DOI: https://doi.org/10.1017/CBO9781139524681

Chun, Dorothy, Smith, Bryan, Kern, Richard. "Technology in Language Use, Language Teaching, and Language Learning". *The Modern Language Journal* 100(S1) (2016): 64-80. DOI: https://doi.org/10.1111/modl.12302

Dmitrenko, Natalia, Budas, Iuliia, Fedyk, Tetiana. "Maximizing University Students' Spoken Interaction in English within the Distance Learning Framework in Wartime". *The Annals of Ovidius University Constanţa. Philology Series* (*Analele Universității „Ovidius" Constanța. Seria Filologie) XXXV*(1) (2024): 227-245. https://litere.univ-ovidius.ro/Anale/volume_2024_1.php

Dmitrenko, Natalia, Voloshyna, Oksana, Kizim, Svitlana, Mnyshenko, Kateryna, Nahorniak, Svitlana. "Smart Education in the Prospective Teachers' Training". *CTE Workshop Proceedings of ACNS Conference on Cloud and Immersive Technologies in Education* 3364 10 (2023): 38-53. DOI: https://doi.org/10.55056/cte.v10.

Dudley-Evans, Tony, St John, Maggie Jo. *Developments in English for Specific Purposes: A Multi-Disciplinary Approach.* Cambridge University Press, (1998).

Fattah, Hejar, Vadivel, Balachandran, Shaban, Ahmad, Shanmugam, Kalaiyarasi. "Enhancing English Language Education: The Impact of AI Integration in the Classroom". *Journal of Humanities and Education Development (JHED)* 5(6) (2024): 116-123. DOI: https://dx.doi.org/10.22161/jhed.5.6.15

Gawate, Sandip. "Artificial Intelligence (AI) Based Instructional Programs in Teaching Learning of English Language". *International Journal of English Language Literature and Translation Studies (IJELR)* 6(4) (2019): 69-73. DOI: https://doi.org/10.33329/ijelr.64.69

Halkiopoulos, Constantinos, Gkintoni, Evgenia. "Leveraging AI in E-Learning: Personalized Learning and Adaptive Assessment through Cognitive Neuropsychology—A Systematic Analysis". *Electronics* 13(18) (2024): 3762. DOI: https://doi.org/10.3390/electronics13183762

Harry, Alexandara. "Role of AI in Education". *Interdiciplinary Journal and Hummanity (INJURITY)* 2 (2023): 260-268. DOI: https://doi.org/10.58631/injurity.v2i3.52

Hutchinson, Tom, Waters, Alan. *English for Specific Purposes: A Learning-Centered Approach.* Cambridge University Press, (1987). DOI: http://dx.doi.org/10.1017/CBO9780511733031

Hwang, Gwo-Jen, Xie, Haoran, Wah, Benjamin, Gasevic, Dragan. "Vision, challenges, roles and research issues of Artificial Intelligence in Education". *Computers and Education: Artificial Intelligence* 1 (2020): 100001. DOI: https://doi.org/10.1016/j.caeai.2020.100001

Jian, Maher. "Personalized learning through AI". *Advances in Engineering Innovation* 5 (2023). DOI: https://doi.org/10.54254/2977-3903/5/2023039

Johns, Ann M. English for Specific Purposes (ESP): Its History and Contributory Fields. In Celce-Murcia, Marianne (Ed.), *Teaching English as a Second or Foreign Language*. Boston, MA: Heinle & Heinle, (1991): 67-77.

Lightfoot, Amy. *New report looks at how artificial intelligence could affect ELT*. British Council, (2023). https://www.britishcouncil.org/voices-magazine/new-report-looks-how-artificial-intelligence-couldaffect-elt

Liu, Chenchen, Hou, Jierui, Tu, Yun-Fang, Wang, Youmei, Hwang, Gwo-Jen. "Incorporating a reflective thinking promoting mechanism into artificial intelligence-supported English writing environments". *Interactive Learning Environments* 31 (2021): 1-19. DOI: https://doi.org/10.1080/10494820.2021.2012812

Nguyen, Nathan. "Exploring the role of AI in education". *London Journal of Social Sciences* 6 (2023): 84-95. DOI: https://doi.org/10.31039/ljss.2023.6.108

Shin, Myeong Hee. "How to use artificial intelligence in the English language learning classroom". *Indian Journal of Public Health Research & Development* 9(9) (2018): 557-561. DOI: https://doi.org/10.5958/0976-5506.2018.01058.6

Shkola, Iryna. (Ed.) *Digital Technologies for Teaching English as a Foreign/Second Language: A Collective Monograph*. Zhytomyr: Euro-Volyn Publishing House, (2024).

Sussmann, Matthew. "AI Tools for the Four Skills in English Language Learning". *TESOL Connections* April (2024): 2-4. (2024). https://www.tesol.org/articleslist/articles/ai-tools-for-the-four-skills-in-english-language-learning/

Warschauer, Mark, Kern, Richard. *Network-Based Language Teaching: Concepts and Practice.* Cambridge University Press, (2000). DOI: https://doi.org/10.1017/CBO9781139524735

Wu, Yi. "Revolutionizing Learning and Teaching: Crafting Personalized, Culturally Responsive Curriculum in the AI Era." *Creative Education*

15(8) (2024): 1642-1651. DOI: https://doi.org/10.4236/ce.2024.158098

Yang, Siqi. “The Role of AI in Achieving Inclusive Education”. *Communications in Humanities Research* 64(1) (2025): 193-197. DOI: https://doi.org/10.54254/2753-7064/2024.19654

Yu, Qiangfu. “Comprehensive Foreign Language Teaching Mode in the Era of Big Data”. *2021 International Conference on Computers, Information Processing and Advanced Education (CIPAE)* Ottawa (2021): 5-8. DOI: https://doi.org/10.1109/CIPAE53742.2021.00010

Websites and AI Tools

https://www.educaplay.com/
https://www.speechace.com/
https://elsaspeak.com/en/
https://app.getpronounce.com/
https://padlet.com/
https://claude.ai/new
https://twee.com/
https://ttsreader.com/
https://ideogram.ai/t/explore
https://www.bing.com/images/create?FORM=GENILP