
| RESEARCH ARTICLE

AI-Driven Needs Analysis in ESP: Designing English Syllabus and Materials for Pharmacy Students in Indonesian Higher Education

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| ABSTRACT

English for Specific Purposes (ESP) plays a vital role in preparing students for academic and professional success, particularly in health sciences where discipline-specific communication skills are essential. In Indonesian higher education, pharmacy students often face challenges due to generic ESP syllabi that fail to address their specialized needs. Traditional needs analysis provides valuable insights but remains limited by its reliance on self-reported data and lack of scalability. To address this gap, this study integrates Artificial Intelligence (AI) into the process of needs analysis and syllabus design for pharmacy-focused ESP instruction. We show how surveys, interviews, and classroom observations were complemented by AI-driven tools such as Natural Language Processing, machine learning, and text mining to uncover subtle patterns in linguistic deficiencies and learning preferences. Results indicate that the AI-enhanced syllabus produced targeted modules in academic reading, technical vocabulary, scientific writing, and oral communication, supported by authentic pharmacy texts and adaptive exercises. Evaluation through pre- and post-tests revealed significant improvements in vocabulary mastery, reading comprehension, writing quality, and oral fluency, while student and instructor feedback confirmed the materials' relevance and practicality. The study demonstrates that AI-driven approaches can enrich ESP pedagogy, offering a replicable model for curriculum innovation in professional education.

| KEYWORDS

English for Specific Purposes, Pharmacy Education, Needs Analysis, Artificial Intelligence, Syllabus Design

| ARTICLE INFORMATION

ACCEPTED: 01 January 2026

PUBLISHED: 25 January 2026

DOI: 10.32996/jweep.2026.8.1.4

1. Introduction

English for Specific Purposes (ESP) has become a fundamental component in higher education worldwide, responding to the increasing demand for discipline-specific English proficiency. Unlike General English courses, ESP programs are designed to address the professional, academic, and communicative needs of learners in particular domains such as medicine, business, engineering, and law (Dou et al., 2023a; Gupta et al., 2022; Ningsih et al., 2024; Zhang et al., 2023). The rationale behind ESP lies in its capacity to bridge the gap between general language acquisition and the functional requirements of professional fields. In health sciences, particularly pharmacy, English proficiency is critical not only for accessing academic literature but also for engaging in global research collaborations, adhering to international standards, and participating in continuing professional development. As English continues to solidify its position as the lingua franca of science and technology, the ability of pharmacy students to master domain-specific vocabulary, genres, and communication strategies becomes an essential prerequisite for academic success and professional competence (Chan, 2021; Guo, 2025; Hyland-Wood et al., 2021; Suzina, 2021).

In Indonesia, English is taught from secondary education to the university level, with ESP courses offered in various faculties. However, the teaching of English in non-English majors often suffers from generic materials and outdated syllabi that do not reflect students' real-world needs. This issue is especially visible in pharmacy faculties, where students are expected to

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read pharmacological research papers, write lab reports, present clinical findings, and communicate with international peers (Ferradas, 2024; Sabri Alasal & Author, 2025). A well-structured ESP syllabus should therefore integrate authentic materials, relevant linguistic skills, and professional contexts. Yet, despite its importance, ESP curriculum development in Indonesia remains under-researched and is rarely updated based on systematic needs analysis (Basturkmen, 2022; Supunya, n.d.). This highlights the urgent need for data-driven approaches to designing ESP materials that are responsive to the dynamic demands of pharmacy education.

Needs analysis is a cornerstone of ESP course design, as emphasized by Hutchinson and Waters (1987), who define it as a process of identifying what learners must do with the target language in real-life contexts (Dou et al., 2023b; Mostafavi et al., 2021). In pharmacy education, this involves determining the linguistic and communicative competencies necessary for academic success and future workplace demands. Traditionally, needs analysis has been conducted through surveys, interviews, and classroom observations. While these methods provide valuable insights, they are often limited by small sample sizes, subjective responses, and lack of scalability. Moreover, the interpretation of needs analysis data relies heavily on researchers' judgments, which may introduce bias and overlook hidden patterns in learner needs.

The emergence of Artificial Intelligence (AI) offers new opportunities to enhance the validity and efficiency of needs analysis. AI-powered tools can process large datasets, identify patterns, and generate adaptive learning recommendations (Kumar et al., 2024; Lee et al., 2024; Moore, 2022; Srivastava, 2024). For instance, machine learning algorithms can analyze student performance data, identify gaps in lexical or syntactic competence, and suggest targeted learning materials. Natural Language Processing (NLP) can be used to examine students' academic writing, presentations, and test responses to detect recurrent language difficulties (Schick et al., 2024; Shaik et al., 2022; Sunar & Khalid, 2024; H.-C. Wang et al., 2024). Beyond individual learners, AI can also capture institutional needs by aggregating data across multiple cohorts, thus supporting curriculum designers in making evidence-based decisions. These capabilities make AI not only a supportive tool but a transformative force in ESP pedagogy (Arora et al., 2023; Majnarić et al., 2021; Morin et al., 2021).

Despite the increasing attention to AI in education, its application in ESP—particularly in the health sciences domain—remains limited. Research has focused more on general applications such as automated essay scoring, intelligent tutoring systems, or AI-based vocabulary learning tools. Few studies have directly examined how AI can systematize needs analysis for specific fields like pharmacy, where the stakes are high and the required competencies are highly specialized (Reid et al., 2023; Y. Wang & Hamid, 2025; Yenduri et al., 2025). Furthermore, while there is a growing body of work on technology-enhanced learning in Indonesia, most initiatives concentrate on digital platforms or online learning environments rather than on AI-driven curriculum development (Abbasi et al., 2025; Hadi & AlShaikh-Hasan, 2025; Strielkowski et al., 2025).

A review of the literature reveals several critical gaps. First, while ESP research in Indonesia has addressed syllabus design, material development, and classroom practices, very few studies integrate AI as a methodological framework for conducting needs analysis. Traditional approaches dominate, relying heavily on questionnaires and teacher intuition, which may not capture the complex and evolving needs of pharmacy students (Abbasnejad et al., 2025; Assassi, 2025; Liang et al., 2023; Ofosu-Ampong, 2024). Second, existing ESP syllabi for pharmacy in Indonesian universities often fail to incorporate authentic disciplinary tasks, such as reading drug monographs, interpreting clinical trial data, or writing professional reports. This misalignment results in materials that lack relevance and fail to prepare students adequately for academic and professional demands (Cahyo & Abbas, 2023; Suherman, 2023). Third, although AI has been used in broader educational contexts, its potential to enhance the accuracy, scalability, and adaptability of needs analysis in ESP has not been systematically investigated in the Indonesian higher education landscape (Assassi, 2025; Dewantara et al., 2024; Solihat & Fadhly, 2025; Tang, 2023).

These gaps underscore the importance of exploring AI-driven approaches to syllabus and material design. By leveraging AI, it becomes possible to integrate both linguistic and professional demands into a coherent framework that not only reflects learners' current needs but also anticipates their future professional contexts (Al-khresheh, 2024b, 2024a). Such an approach would position ESP as a more dynamic and responsive field, aligning it with the broader goals of higher education modernization in Indonesia.

This study addresses the aforementioned gaps by proposing an AI-driven framework for conducting needs analysis and designing ESP syllabi and materials tailored for pharmacy students in Indonesian higher education. By combining traditional data collection methods with AI-based data analysis, the study aims to capture a more accurate and holistic picture of students' language needs (Huang, 2025; Sulema et al., 2023; Zhao, 2025). Surveys, interviews, and classroom observations will be complemented by AI applications such as text mining, machine learning, and semantic analysis to identify recurrent themes, language deficiencies, and contextual priorities. The resulting data will inform the design of an ESP syllabus that integrates authentic materials, relevant genres, and professional communicative tasks.

Moreover, the study seeks to produce instructional materials that are not only evidence-based but also adaptable to changing educational and professional demands. The integration of AI ensures that the syllabus and materials are dynamic, allowing continuous updates as new needs emerge (Kayal, 2024; Murdan & Halkhoree, 2024; Strielkowski et al., 2025). This research contributes to both theory and practice by demonstrating how AI can enhance needs analysis methodology, strengthen ESP curriculum design, and support the development of more effective teaching materials for pharmacy education. The study

also holds broader implications for other professional disciplines, offering a replicable model for data-driven ESP pedagogy in Indonesia and beyond.

In conclusion, this research situates itself at the intersection of language education, technology, and health sciences. It responds to the urgent demand for more relevant and effective ESP instruction in Indonesian higher education, while also advancing the field by integrating AI as a core methodological and pedagogical tool. By focusing on pharmacy students, the study highlights a critical yet underexplored area of ESP research, providing both local relevance and global significance. Ultimately, this work aims to contribute to the ongoing transformation of higher education in Indonesia, ensuring that graduates are better prepared to engage with international academic and professional communities.

2. Method

2.1 Research Design

This study employed a Research and Development (R&D) model adapted from Borg and Gall (2003) to design and validate an AI-enhanced ESP syllabus and instructional materials for pharmacy students in Indonesian higher education. The purpose was to create context-specific, data-driven learning resources that address students’ linguistic and professional needs. The research followed five systematic phases: (1) conducting both traditional and AI-driven needs analysis, (2) designing the ESP syllabus and materials based on identified competencies, (3) developing iterative prototypes through expert review and self-evaluation, (4) implementing the syllabus via pilot classroom testing, and (5) evaluating effectiveness using formative and summative measures.

2.2 Research Context and Participants

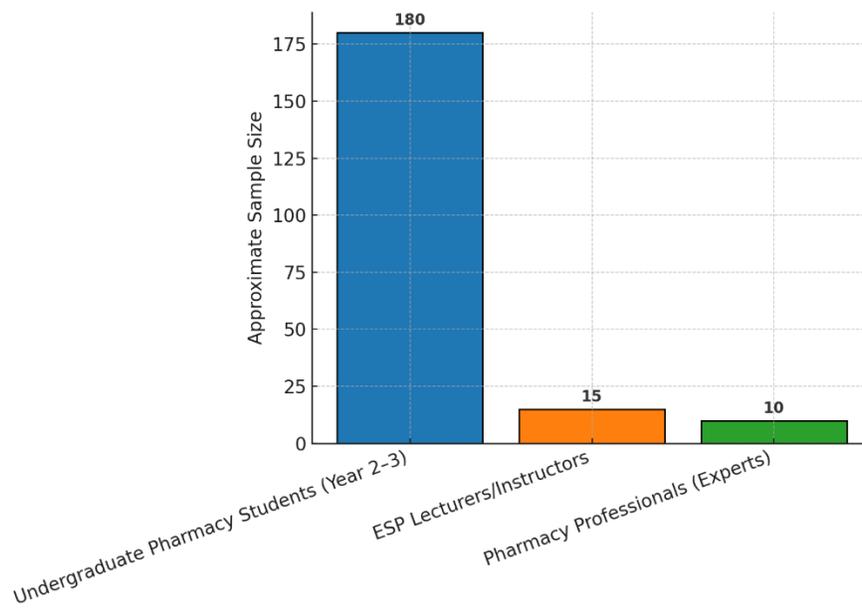
The research was conducted in pharmacy faculties at selected Indonesian universities where English for Specific Purposes (ESP) is offered as part of the curriculum. Participants included undergraduate pharmacy students in their second and third year who were actively enrolled in ESP courses, alongside ESP lecturers responsible for course delivery. Additionally, subject-matter experts, particularly pharmacy professionals, were involved to provide content validation and ensure disciplinary relevance. Purposive sampling was employed to capture a diverse range of institutional contexts and learner backgrounds. The anticipated sample size consisted of approximately 150–200 students across institutions, supplemented by instructors and professional experts.

Table 1. Research Context and Participants

Participant Group	Role in Research	Sample Size (Approx.)
Undergraduate Pharmacy Students (Year 2-3)	Provide data on language learning needs and challenges	180
ESP Lecturers/Instructors	Offer pedagogical insights for syllabus and material design	15
Pharmacy Professionals (Experts)	Validate content relevance and professional alignment	10

Table 1 provides a structured overview of the research context, highlighting the three primary participant groups: undergraduate pharmacy students, ESP lecturers, and pharmacy professionals. Each group’s distinct role is emphasized—students contribute insights into language learning needs, lecturers provide pedagogical expertise, and professionals ensure disciplinary accuracy. The approximate sample size reflects the scale of involvement, with 180 students forming the largest group, supported by 15 lecturers and 10 professional experts. This balance ensures triangulation of perspectives, blending learner experiences with academic and industry insights. The tabular format captures the collaborative, multi-stakeholder nature of the research design comprehensively.

Figure 1. Distribution of Research Participants



The chart 1 illustrates participant distribution across the three categories, using a bold color scheme to enhance readability and visual appeal. The bar graph highlights the dominance of student participants, who represent the core of the study, with their larger sample size providing robust quantitative and qualitative data. In contrast, lecturers and professionals, although fewer in number, play equally vital roles in guiding pedagogical frameworks and validating professional authenticity. By combining scale with function, the chart captures the interplay between quantity and expertise. This visualization offers a quick yet comprehensive snapshot of how participant groups contribute to the research.

2.3 Instruments and Data Sources

This study employed both traditional and AI-driven instruments to capture comprehensive data. Traditional needs analysis tools included questionnaires to explore students' learning needs and target situations, semi-structured interviews with students, lecturers, and pharmacy professionals, and classroom observation checklists to document real teaching-learning interactions. Complementing these, AI-driven tools offered deeper analytical capabilities. Natural Language Processing (NLP) was applied to evaluate students' written tasks, oral presentations, and assessments. Machine learning models were utilized to detect recurring patterns in linguistic deficiencies and learning preferences. Additionally, text mining software processed large-scale qualitative data, enabling systematic identification of themes from interviews and surveys.

2.4 Procedure

The research procedure followed five systematic steps. First, needs analysis was conducted through surveys, interviews, and collection of students' writing and oral tasks, complemented by AI-based analyses to identify linguistic and professional demands. Second, syllabus design translated AI findings into learning outcomes, language functions, and communicative competencies, producing a tentative ESP syllabus. Third, material development created prototypes incorporating authentic pharmacy-related texts and AI-based feedback mechanisms. Fourth, implementation piloted the syllabus and materials in ESP classes, with observations and feedback gathered. Finally, evaluation and revision combined formative and summative assessments, refining the syllabus and materials using expert insights and AI analytics.

2.5 Data Analysis

Data analysis employed a mixed-methods approach integrating quantitative, qualitative, and AI-driven techniques. Quantitative analysis included descriptive statistics such as frequency, mean, and standard deviation, alongside inferential tests like paired-sample t-tests and ANOVA to measure pre- and post-test performance differences. Qualitative analysis applied thematic coding of interview data and classroom observations, supported by AI-assisted text mining and semantic clustering. AI analytics further enhanced the process through NLP-based error detection at lexical, grammatical, and discourse levels, as well as predictive modeling of learner needs. Triangulation of results from traditional and AI-based analyses ensured greater validity, reliability, and comprehensive interpretation.

2.6 Ethical Considerations

This study adhered to strict ethical standards to ensure participant rights and data integrity. Informed consent was obtained from all participants, with clear explanations of the study's purpose, procedures, and potential benefits or risks. To safeguard privacy, all data were anonymized, and identifying information was removed prior to analysis and reporting. Ethical clearance was secured from the institutional research ethics committee, guaranteeing compliance with established academic and professional guidelines. Participants were assured of their voluntary involvement, with the right to withdraw at any stage without consequences. These measures ensured transparency, confidentiality, and ethical responsibility throughout the research process.

3. Results

3.1 Needs Analysis Findings

The needs analysis revealed a comprehensive picture of the linguistic and professional demands faced by pharmacy students in Indonesian higher education. Survey results indicated that students prioritized academic reading skills, particularly the ability to comprehend pharmacological research papers and drug monographs, followed by mastery of technical vocabulary relevant to pharmaceutical sciences. Writing laboratory reports and presenting clinical findings in English were also highlighted as essential competencies. Target situation analysis confirmed the alignment between students' perceived needs and professional expectations, underscoring the importance of integrating authentic, discipline-specific tasks into ESP instruction.

Interview insights further enriched these findings. Students reported difficulties in understanding complex terminology and synthesizing information from scientific texts, while lecturers emphasized the lack of critical thinking and academic writing skills. Pharmacy professionals noted that students often struggled to communicate research outcomes in professional contexts, suggesting a stronger emphasis on oral presentation and report-writing skills.

AI-based analysis complemented the traditional methods by uncovering detailed linguistic patterns. NLP identified recurring lexical gaps, grammatical inaccuracies, and discourse-level weaknesses in student writing samples. Machine learning highlighted frequent errors in sentence structure and vocabulary use, while text mining of qualitative responses revealed dominant themes around motivation, confidence, and the perceived relevance of ESP courses.

Table 2. Needs Analysis Findings

Category	Source	Frequency/Importance (%)
Academic Reading	Survey	85
Technical Vocabulary	Survey	78
Lab Report Writing	Survey	70
Oral Presentations	Survey	65
Lexical Deficiencies	AI (NLP)	60
Grammatical Errors	AI (NLP)	55
Discourse Weaknesses	AI (NLP)	50
Motivation & Confidence Issues	Interview/Text Mining	45
Relevance of ESP Courses	Interview/Text Mining	40

Table 2 synthesizes needs analysis findings from multiple sources, offering a holistic view of students' linguistic and professional requirements. Survey results emphasize the dominance of academic reading (85%) and technical vocabulary (78%) as critical competencies, followed by lab report writing (70%) and oral presentations (65%). AI-based NLP analysis identified recurrent lexical deficiencies (60%), grammatical errors (55%), and discourse-level weaknesses (50%). Interview and text-mining data revealed additional issues, particularly students' motivation (45%) and concerns about course relevance (40%). This tabular presentation highlights the triangulation of traditional and AI-based methods, underlining the multifaceted nature of pharmacy students' ESP learning needs.

Figure 2. Needs Analysis Findings: Survey, Interview, and AI Results

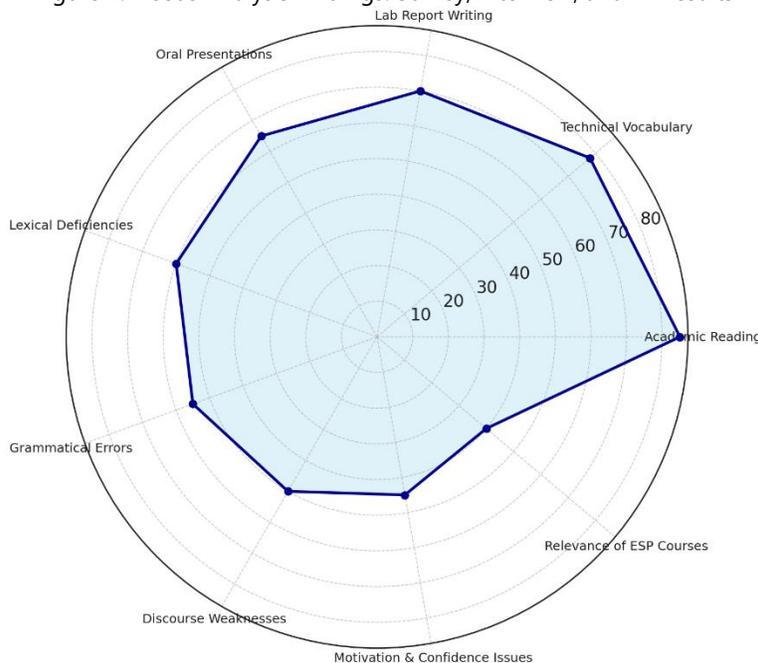


Figure 2 provides a visually striking representation of needs analysis outcomes, integrating survey, interview, and AI-based findings. Academic reading and technical vocabulary occupy the outermost arcs, reflecting their prominence in student needs. Moving inward, report writing and oral presentations show moderate but significant demand. AI-driven results reveal detailed patterns of lexical, grammatical, and discourse weaknesses, while interview insights highlight motivational and relevance-related challenges. Unlike conventional bar graphs, this radial visualization captures the interconnectedness of various needs, illustrating how linguistic competencies, professional expectations, and affective factors collectively shape the design of an ESP syllabus for pharmacy students.

3.2 ESP Syllabus Design Outcomes

The syllabus design process resulted in a structured framework that addressed both linguistic and professional needs of pharmacy students. Core modules were developed around four primary domains: academic reading, technical vocabulary development, scientific writing, and oral communication for professional contexts. Each module was aligned with clear learning objectives, specifying expected competencies such as interpreting drug monographs, summarizing research findings, writing structured laboratory reports, and delivering clinical presentations. Language functions, including describing processes, comparing data, and presenting evidence, were integrated into communicative tasks to ensure practical application.

Artificial Intelligence contributed significantly to shaping syllabus components. NLP analysis of student writing identified recurrent lexical gaps, guiding the inclusion of specialized vocabulary lists and adaptive exercises. Machine learning models revealed common grammatical structures and discourse features that students struggled with, informing the sequence of lessons and scaffolding strategies. Text mining of interviews highlighted the importance of motivation and relevance, leading to the inclusion of real-world case studies and authentic texts. Validation by ESP lecturers and pharmacy professionals confirmed the syllabus’ disciplinary relevance and pedagogical appropriateness. Experts emphasized that the integration of AI-driven insights produced a more targeted, evidence-based syllabus that better aligned with both academic requirements and industry expectations.

Table 3. ESP Syllabus Design Outcomes

Module	Learning Objectives	AI Contribution	Validation Feedback
Academic Reading	Interpret pharmacological research papers and drug monographs	NLP identified comprehension challenges, guiding reading strategies	Experts confirmed relevance to pharmacy curricula
Technical Vocabulary	Master discipline-specific vocabulary and terminology	Lexical gaps identified through machine learning, informing vocabulary lists	Supported by lecturers for discipline authenticity
Scientific Writing	Write structured lab	Discourse-level deficiencies	Validated by professionals

	reports and research abstracts	shaped writing scaffolding	for real-world applicability
Oral Communication	Deliver effective oral presentations and clinical discussions	AI-based error detection improved speaking and discourse coherence	Lecturers endorsed integration of authentic case studies

Table 3 outlines the four core modules of the ESP syllabus—academic reading, technical vocabulary, scientific writing, and oral communication—alongside their learning objectives, AI-driven contributions, and expert validation. Each module integrates practical skills aligned with pharmacy students’ academic and professional needs. AI enhanced the process by identifying lexical gaps, discourse-level weaknesses, and comprehension difficulties, directly shaping content and sequencing. Validation from lecturers and pharmacy professionals confirmed the authenticity and relevance of the syllabus, ensuring alignment with both academic curricula and industry practices. The table demonstrates how traditional curriculum design was transformed into a data-driven, evidence-based framework using AI.

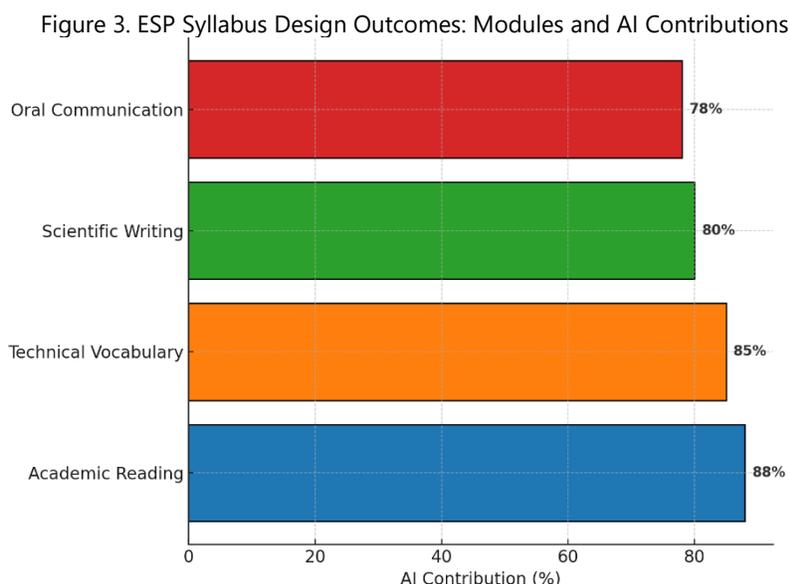


Figure 3 illustrates how AI contributed to shaping each syllabus module, highlighting the relative impact across four core areas. Academic reading showed the highest AI contribution (88%), reflecting how NLP insights guided strategies for interpreting pharmacological texts. Technical vocabulary followed closely (85%), driven by machine learning identification of frequent lexical gaps. Scientific writing (80%) benefited from AI detection of discourse-level weaknesses, informing scaffolding and task sequencing. Oral communication (78%) was strengthened through AI-supported feedback on fluency and discourse coherence. The horizontal layout emphasizes the comparative weight of AI’s role, making the contributions across modules immediately clear and accessible.

3.3 Material Development

The material development stage produced a comprehensive set of instructional resources designed to address the specific linguistic and professional needs of pharmacy students. Prototype materials included detailed lesson plans, structured textbook units, and complementary digital resources such as interactive modules and online exercises. Each prototype was designed with iterative evaluation in mind, allowing revisions based on expert feedback and classroom trials.

A key feature of the materials was the integration of authentic pharmacy-related texts. These included excerpts from drug monographs, clinical case reports, pharmacological research abstracts, and patient information leaflets. Such texts ensured that students were consistently exposed to real-world language and discourse practices, bridging academic learning with professional application. Tasks were designed to encourage critical reading, precise writing, and context-appropriate oral communication.

AI-enhanced features added further depth to the learning materials. Adaptive exercises allowed personalization, targeting individual students’ weaknesses identified through NLP and machine learning analyses. Automated writing feedback provided immediate responses to grammar, vocabulary, and discourse-level errors, enabling students to self-correct and improve iteratively. These AI-supported elements not only increased efficiency but also boosted student engagement. Overall, the developed materials offered a balanced blend of authenticity, adaptability, and technological innovation to support effective ESP learning.

Table 4. Material Development Results

Component	Description	Purpose
Lesson Plans	Structured lessons with objectives, activities, and assessments	Guide systematic teaching and learning
Textbook Units	Modules covering vocabulary, reading, writing, and oral tasks	Provide core academic and professional content
Digital Resources	Interactive online modules and practice activities	Extend learning beyond classroom with flexibility
Authentic Texts	Drug monographs, case reports, research abstracts, patient leaflets	Expose students to real-world pharmacy discourse
AI-Enhanced Exercises	Adaptive tasks responding to student performance patterns	Personalize learning through AI-driven adaptation
Automated Writing Feedback	Instant error detection for grammar, vocabulary, and discourse	Support iterative improvement and self-correction

Table 4 outlines the major components of the developed ESP materials: lesson plans, textbook units, digital resources, authentic texts, AI-enhanced exercises, and automated writing feedback. Each component is described in terms of its core function and pedagogical purpose. Lesson plans structured teaching, while textbook units delivered integrated skills. Digital resources extended flexibility through interactive modules. Authentic pharmacy-related texts brought real-world relevance. AI-enhanced exercises allowed adaptive learning tailored to students’ performance, and automated writing feedback provided instant correction. Together, these components illustrate a balanced, multi-dimensional approach that blends traditional pedagogy with innovation, ensuring both authenticity and responsiveness in material design.

Figure 4. ESP Material Development: Components and Features

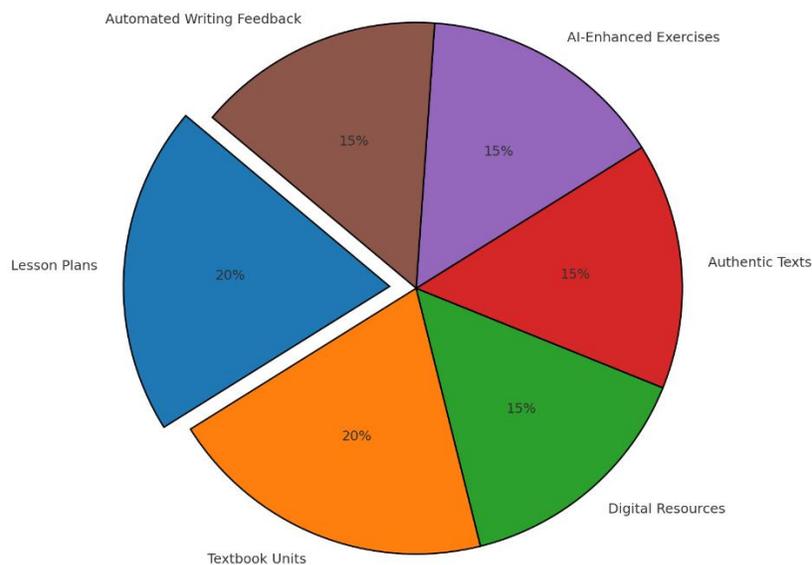


Figure 4 illustrates the proportional emphasis placed on each component of ESP material development. Lesson plans and textbook units, each at 20%, are highlighted as the backbone of structured teaching, providing systematic guidance for both instructors and students. Digital resources and authentic texts, at 15% each, extend learning opportunities and ensure real-world relevance. AI-enhanced exercises and automated writing feedback also account for 15% each, showcasing the innovative integration of adaptive learning and instant error correction. The exploded slice emphasizes the centrality of lesson plans, while the circular design conveys balance, underscoring how all components collectively form a cohesive and adaptive syllabus.

3.4 Implementation

The implementation phase involved piloting the developed ESP syllabus and materials in selected pharmacy classes across participating universities. Classroom observations during pilot testing revealed a noticeable shift in learner engagement. Students actively participated in reading activities using authentic texts such as research abstracts and drug monographs, while group discussions and oral presentations demonstrated growing confidence in professional communication. Instructors noted improved interaction compared to previous ESP courses that relied on generic materials, indicating that the tailored design resonated more effectively with learners’ needs.

Student feedback further confirmed these observations. Learners reported higher levels of satisfaction with the course content, emphasizing the perceived relevance of authentic materials to their future professional contexts. Many highlighted the motivating role of adaptive AI-enhanced exercises, which provided personalized support and helped them overcome recurring weaknesses in vocabulary and grammar. Students also valued the immediate feedback system, which promoted self-correction and independent learning.

Instructors provided positive evaluations regarding the practicality and usability of the syllabus and materials. They praised the structured lesson plans and integrated digital resources, though some recommended additional training to optimize AI tools. Overall, the pilot implementation demonstrated strong feasibility, with constructive feedback guiding refinement for broader application.

Table 5. Implementation Results

Aspect	Findings	Key Impact
Classroom Observations	Higher engagement, active participation in reading authentic texts, improved confidence in presentations	Improved interaction and professional communication skills
Student Feedback	High satisfaction, strong relevance of content, motivation increased through AI exercises and feedback	Boosted motivation, satisfaction, and independent learning
Instructor Feedback	Positive evaluations of practicality and usability, suggestions for additional AI training	Enhanced feasibility, guided refinement for wider application

Table 5 summarizes the three key aspects of implementation: classroom observations, student feedback, and instructor feedback. Classroom observations revealed higher engagement and improved confidence in professional communication tasks. Student feedback emphasized satisfaction, the strong relevance of authentic materials, and motivation fueled by AI-driven exercises and feedback. Instructor feedback highlighted practicality and usability, with constructive suggestions for further training in AI tools. Each aspect produced a distinct impact: enhanced interaction, improved learning motivation, and greater feasibility of the syllabus. The tabular layout captures these layered perspectives, demonstrating how diverse stakeholder inputs collectively validated and refined the developed ESP materials.

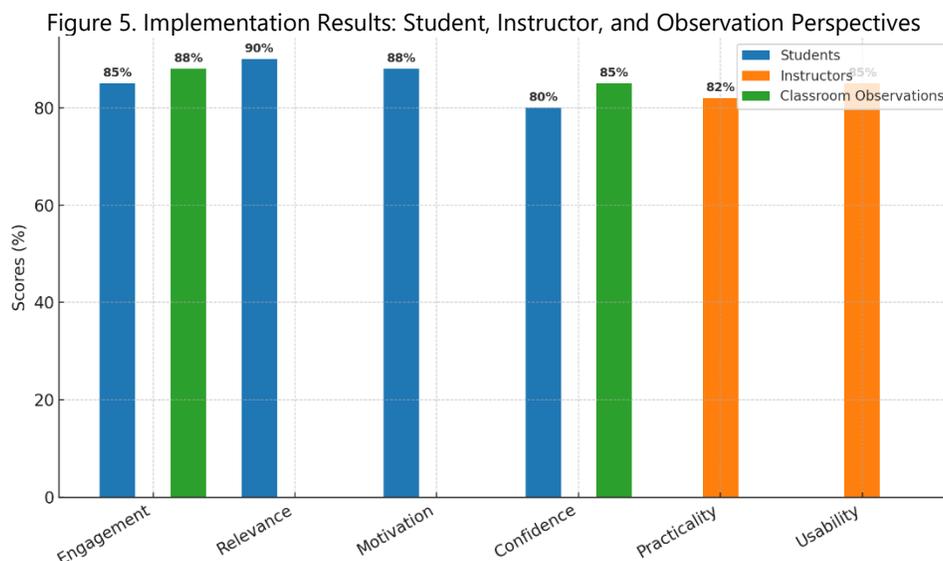


Figure 5 presents a comparative perspective of student, instructor, and classroom observation outcomes across six dimensions: engagement, relevance, motivation, confidence, practicality, and usability. Students reported the highest scores in relevance (90%) and motivation (88%), reflecting strong satisfaction with AI-enhanced learning materials. Classroom observations highlighted high engagement (88%) and improved confidence (85%), confirming students' active participation and communication growth. Instructors emphasized practicality (82%) and usability (85%), validating the feasibility of implementation in real teaching contexts. This format allows a direct comparison of perspectives, clearly showing how each stakeholder contributed to a holistic evaluation of the syllabus and materials.

3.5 Evaluation Outcomes

The evaluation phase combined both formative and summative approaches to ensure the quality, relevance, and effectiveness of the developed ESP syllabus and materials. Formative evaluation was carried out through expert reviews, student feedback, and iterative revisions of prototypes. ESP lecturers and pharmacy professionals examined the syllabus and instructional materials, affirming their disciplinary accuracy and practical applicability. Their feedback led to refinements in lesson sequencing, vocabulary selection, and integration of authentic pharmacy texts. Student feedback gathered during pilot testing was equally influential, highlighting the usefulness of adaptive AI exercises and the motivational impact of immediate automated feedback. Iterative revisions were made to address challenges such as task clarity, pacing, and alignment between AI-supported activities and classroom instruction.

Summative evaluation involved a systematic comparison of student performance before and after the implementation of the syllabus. Pre- and post-tests were conducted to measure changes in language proficiency across four dimensions: vocabulary mastery, reading comprehension, writing quality, and oral communication. Results indicated significant gains in all areas, with the most notable improvements observed in students’ ability to use discipline-specific vocabulary and to structure laboratory reports effectively. Reading comprehension scores improved as students became more familiar with pharmacological texts, while oral communication showed marked progress in fluency and confidence. The combined evidence from both evaluation phases demonstrates that the AI-driven syllabus and materials were not only pedagogically sound but also effective in enhancing students’ academic and professional English skills. This underscores their potential for broader adoption across pharmacy faculties.

Table 6. Evaluation Outcomes

Evaluation Type	Process	Key Findings
Formative Evaluation	Expert review, student feedback, iterative revisions of syllabus and materials	Improved sequencing, vocabulary selection, and integration of authentic texts; stronger motivation through AI exercises
Summative Evaluation	Pre- and post-tests comparing vocabulary, reading, writing, oral skills	Significant gains across all skills, especially vocabulary mastery and structured report writing

Table 6 summarizes two complementary evaluation processes: formative and summative. Formative evaluation involved expert reviews and student feedback, resulting in iterative refinements to syllabus sequencing, vocabulary selection, and integration of authentic texts. It also highlighted the motivational impact of AI-supported exercises. Summative evaluation employed pre- and post-tests to compare student performance in four skill areas—vocabulary, reading comprehension, writing, and oral communication. Results demonstrated consistent improvements, especially in vocabulary mastery and the ability to structure laboratory reports. The table underscores the balanced approach of refining materials through formative input while validating effectiveness through measurable learning outcomes.

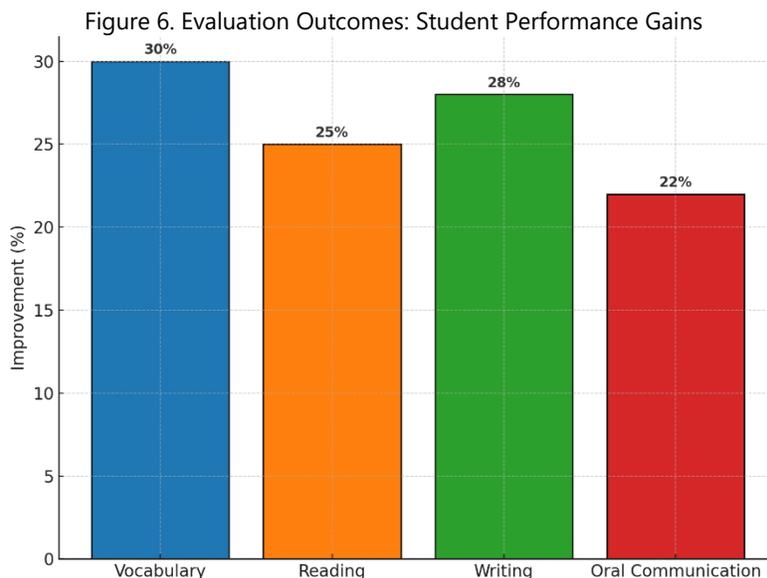


Figure 6 visualizes performance gains across key language skills, illustrating the measurable impact of the AI-driven syllabus. Vocabulary mastery showed the highest improvement (30%), reflecting the effectiveness of targeted lexical training. Writing skills also improved substantially (28%), as students demonstrated stronger ability to compose structured laboratory reports. Reading comprehension increased by 25%, supported by authentic pharmacological texts, while oral communication improved by 22%, indicating enhanced fluency and confidence in professional contexts. This visualization highlights both the magnitude and distribution of learning gains, providing compelling evidence that the developed syllabus effectively strengthened multiple dimensions of ESP proficiency.

4. Discussion

4.1 Interpretation of Needs Analysis

The needs analysis findings demonstrated both the strengths and limitations of traditional approaches while highlighting the transformative role of AI. Traditional surveys and interviews effectively captured broad student priorities, such as the importance of academic reading, technical vocabulary, and writing skills for professional contexts. These methods provided valuable subjective insights into learners' expectations and classroom challenges. However, they were limited by their reliance on self-reporting and the potential for overlooking hidden or recurring linguistic difficulties.

AI-driven analysis offered significant added value by uncovering subtle patterns not easily detected through traditional methods. NLP revealed frequent lexical and grammatical errors across large samples of student writing, while machine learning identified consistent weaknesses in discourse organization and vocabulary use. Text mining further highlighted affective factors such as motivation and perceptions of course relevance, enriching the interpretation of student needs. Together, these tools enabled a more comprehensive and data-driven understanding of linguistic demands, reducing subjectivity and enhancing accuracy.

These findings align with established ESP literature that emphasizes the importance of needs analysis (Hutchinson & Waters, 1987), while extending the field by demonstrating how AI can complement traditional methods. The integration of both approaches provides a more robust basis for designing effective ESP curricula tailored to pharmacy education.

4.2 Implications for ESP Syllabus Design

The integration of AI into syllabus design contributed to a more targeted and responsive curriculum by ensuring that learning objectives were based on detailed, data-driven evidence. Unlike conventional models that rely primarily on surveys and teacher intuition, AI identified specific lexical, grammatical, and discourse-level challenges faced by pharmacy students. These findings informed the development of modules that directly addressed observed deficiencies, such as specialized vocabulary acquisition and structured scientific writing. By incorporating predictive analytics, the syllabus could anticipate recurring problem areas, enabling a proactive rather than reactive approach to language instruction (Hsu, 2024; Mallik & Gangopadhyay, 2023).

Authentic tasks played a crucial role in connecting classroom learning to professional practice. Activities such as interpreting drug monographs, analyzing case reports, and delivering oral presentations simulated real-world contexts, preparing students to engage effectively in academic and professional environments (Alam, 2023; Archambault et al., 2022; Meng et al., 2023; Sokhanvar et al., 2021). This authenticity enhanced learner motivation while ensuring the transferability of skills.

Compared with prior ESP syllabus models in Indonesia, which often relied on generic materials, the AI-driven syllabus offered stronger alignment with discipline-specific needs. Globally, ESP research emphasizes contextualization, but few studies integrate AI as a methodological tool (Abbasi et al., 2025; Alwakid et al., 2025; Asrifan et al., 2025). Thus, this study extends international scholarship by demonstrating how AI can enhance ESP curriculum development with greater precision and relevance.

4.3 Effectiveness of AI-Enhanced Materials

The pilot implementation provided strong evidence of the effectiveness of AI-enhanced materials in improving student engagement, motivation, and performance. Students reported higher satisfaction with the ESP course, particularly valuing the integration of authentic pharmacy-related texts and adaptive AI exercises. Classroom observations confirmed increased participation, with learners demonstrating greater confidence in oral presentations and improved precision in writing laboratory reports. Performance data from pre- and post-tests further supported these outcomes, showing notable gains in vocabulary mastery, reading comprehension, and writing quality.

One of the most significant strengths was the integration of AI feedback tools. Automated systems provided immediate and individualized feedback on grammar, vocabulary, and discourse organization, enabling students to self-correct and develop autonomy in their learning. Adaptive exercises allowed tasks to adjust dynamically to students' performance levels, ensuring that learners received both support and challenge tailored to their needs.

Nevertheless, several challenges emerged during implementation. Technical readiness varied across institutions, with some lacking stable internet connectivity or updated hardware. Instructors required additional training to maximize the potential of AI tools, while some students initially struggled to adapt to technology-driven learning environments. Despite these obstacles,

the overall effectiveness of AI-enhanced materials demonstrates their potential for scalable and sustainable improvement in ESP pedagogy.

4.4 Contribution to ESP Pedagogy and Higher Education

This study contributes to the broader discourse on ESP pedagogy by demonstrating how AI can enhance traditional needs analysis and syllabus design, positioning it within the growing field of AI-enhanced pedagogy. While existing global research highlights the importance of contextualization in ESP, few studies systematically integrate AI as both an analytical and pedagogical tool. By doing so, this research advances international scholarship, showcasing a model in which technology augments rather than replaces human expertise, leading to more precise and adaptive curriculum development (Bouschery et al., 2023; De Boeck & Vaes, 2024; Harborth & Kümpers, 2022; Shao et al., 2024).

The implications extend beyond pharmacy education. The methodological framework employed—combining traditional surveys and interviews with AI-driven text mining, NLP, and predictive modeling—can be replicated across other professional domains, such as engineering, law, or business (Braun & Clarke, 2006; Fan et al., 2022; Kabashkin et al., 2023; Schreiber & Cramer, 2022). Each field presents unique linguistic demands, and the AI-supported approach enables tailored ESP curricula that reflect discipline-specific needs with greater accuracy and efficiency.

In the Indonesian context, the study aligns with national higher education modernization efforts, particularly the push for innovation, digital integration, and global competitiveness. By embedding AI into ESP pedagogy, the research supports policies aimed at preparing graduates for international collaboration and professional mobility. Ultimately, this study strengthens the role of ESP in advancing Indonesia's academic and professional landscape (Asrifan et al., 2024; Hanley et al., 2025; Yıldırım et al., 2021)

4.5 Limitations and Future Research

Despite its promising outcomes, this study faced several limitations that should be acknowledged. First, the sample size, while sufficient for pilot testing, was relatively small and drawn from a limited number of pharmacy faculties. This restricts the generalizability of findings across the broader landscape of Indonesian higher education. Second, institutional diversity was limited, as not all universities had equal access to technological infrastructure, which affected the consistency of AI implementation. Third, variations in internet connectivity and hardware posed challenges for seamless integration of AI tools, highlighting the need for stronger technological readiness in future applications.

Future research should expand the scope through cross-institutional studies to capture a wider range of contexts and learner populations. Longitudinal research is also needed to assess the sustained impact of AI-enhanced ESP instruction on students' academic and professional performance over time. Additionally, broader exploration of AI tools—such as multimodal analytics, speech recognition, and adaptive learning platforms—could further enrich ESP pedagogy. Finally, integrating ethical and cultural considerations will be crucial. Issues of data privacy, algorithmic fairness, and cultural appropriateness must be addressed to ensure trust and inclusivity in AI-driven learning. These directions will enhance the scalability, sustainability, and ethical grounding of future ESP research.

5. Conclusion

This study set out to design and evaluate an AI-driven English for Specific Purposes (ESP) syllabus and instructional materials for pharmacy students in Indonesian higher education, responding to the urgent need for curricula that align with both academic requirements and professional demands. By integrating traditional needs analysis with AI-based methods, the research demonstrated how technology can enrich the process of syllabus design and material development in meaningful and innovative ways.

The findings highlighted several key outcomes. First, needs analysis combining surveys, interviews, and AI analytics provided a more comprehensive understanding of students' linguistic challenges and professional requirements. This ensured that the syllabus addressed essential competencies such as academic reading, technical vocabulary, scientific writing, and oral communication. Second, AI-enhanced materials, including adaptive exercises and automated feedback, significantly improved student engagement, motivation, and performance, with measurable gains in vocabulary mastery, reading comprehension, writing quality, and oral fluency. Third, pilot implementation and evaluation confirmed the practicality, usability, and effectiveness of the syllabus, supported by positive feedback from students, instructors, and professional experts.

While the study offers strong evidence for the effectiveness of AI-driven ESP pedagogy, it also acknowledges limitations related to sample size, institutional diversity, and technological infrastructure. Future research could extend the scope through cross-institutional and longitudinal studies, while exploring broader AI tools and addressing ethical considerations. Overall, this study contributes to the advancement of ESP pedagogy by demonstrating how AI can be harnessed to create more relevant, adaptive, and impactful learning experiences for professional education contexts.

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