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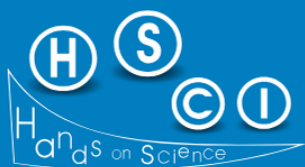
Resilience in challenging times



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The Hand-on Science Network



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Science Education. Resilience in challenging times

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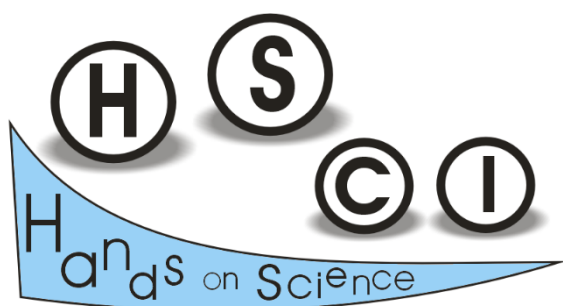
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Chapter 28: Enhancing the Professional Technical Communication Skills of Engineering Students via Generative AI Integration in ESP Training

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Abstract. This article explores the integration of Generative Artificial Intelligence (GenAI) into English for Specific Purposes (ESP) training to enhance the professional technical communication skills of engineering students. Drawing on contemporary pedagogical frameworks, we analyze how Large Language Models can scaffold technical writing, academic self-efficacy, and specialized vocabulary. Grounded in Swales' genre analysis and Activity Theory, we examine conversational AI agents and prompt engineering as rhetorical competencies. Finally, we address critical risks - such as factual hallucinations, plagiarism, and data privacy - advocating for a human-centric model of ethical stewardship in Industry 4.0.

Keywords. English for Specific Purposes, Generative Artificial Intelligence, Professional Technical Communication, Prompt Engineering.

1. Introduction

In the contemporary globalized economy, English serves as the primary instrument for professional mobility, participation in international projects, and interdisciplinary collaboration within the engineering domain. Consequently, English for Specific Purposes training must evolve beyond simple vocabulary acquisition to address the complex, holistic communicative demands of the workplace, where language is inseparable from documentation, teamwork, and decision-making. However, traditional ESP instruction in technical universities faces persistent challenges, including outdated teaching materials, constrained class hours, and a lack of specialized discourse knowledge among educators who are primarily trained in general English.

The rapid advancement and deployment of

Generative Artificial Intelligence (GenAI), particularly Large Language Models (LLMs), represents a profound pedagogical turning point. Far from being a mere writing aid or source of academic dishonesty, GenAI introduces a paradigm shift by enabling dynamic, context-aware content generation and personalized feedback. This article examines the strategic integration of GenAI in engineering ESP curricula to enhance students' writing self-efficacy, specialized technical communication, and conversational skills. We argue that by treating GenAI not as a replacement for human capability but as a structured pedagogical instrument, educators can cultivate a symbiotic human-machine collaboration that prepares engineering students to lead as ethical, highly capable technical professionals.

To operationalize this model effectively, curricula must combine interactive simulations with rigorous analytical editing to target multiple levels of cognitive development. By confronting the distinct structural differences and qualitative gaps between human writing and machine outputs, students learn to approach automated text with a critical mindset. This active evaluation forces learners to cross-reference machine drafts with authentic industry benchmarks, moving them away from passive reliance on technology. Furthermore, engaging with specialized conversational tools helps lower foreign language anxiety while simultaneously fostering essential workplace competencies like professional adaptability and collaborative problem-solving. Ultimately, this comprehensive digital literacy equips future engineers with the advanced rhetorical judgment necessary to act as responsible, context-aware human stewards of automated information systems [16], [17].

2. Scaffolding Genre Awareness and Specialized Vocabulary

Developing professional technical communication skills within English for Specific Purposes requires more than a surface-level grasp of grammar; it demands a deep, structural understanding of domain-specific genres and highly precise, industry-standard terminology. In contemporary engineering education, Generative AI-powered conversational models have emerged as highly effective, adaptive tools for generating tailored ESP materials. Instructors can leverage these systems to provide simplified, multi-tiered explanations of

abstract concepts and to produce customized vocabulary exercises that adapt to varying student proficiency levels. Furthermore, this technological integration allows for the rapid creation of realistic technical scenarios that mirror actual workplace challenges. By interacting with these models, students can practice navigating complex professional dialogues, such as client briefings and collaborative project meetings, in a low-stakes environment. This automated personalization ensures that learners receive targeted linguistic support exactly where they struggle most, optimizing the overall instructional workflow. Ultimately, using GenAI as a flexible pedagogical resource empowers educators to efficiently bridge the gap between classroom theory and real-world industrial practice.

For instance, in highly specialized and high-stakes domains such as aerospace engineering, educators can compile comprehensive, domain-specific corpora from authentic research papers and industry reports. They can then utilize GenAI as a complementary, interactive tool to generate contextualized drafting exercises, bridging the gap between passive reading and active technical writing. This localized corpus-driven methodology guarantees that the training inputs remain closely aligned with the actual linguistic evolution of the sector. By working with simulated engineering briefs derived from these corpora, learners develop an operational familiarity with the exact phrasing, structural conventions, and informational densities expected in industrial documentation. Furthermore, this target-oriented exposure helps students recognize when an automated tool falls short of industry standards. Ultimately, grounding the AI's inputs in authenticated technical literature ensures that the resulting exercises remain highly relevant to current engineering practices [8].

The core strength of this pedagogical approach lies in its systematic design, specifically using delta proficiency (ΔP) to prioritize instructional targets based on identified student learning gaps. Once these targets are established, they are structured into a progressive series of tasks carefully aligned with Bloom's Revised Taxonomy.

In modern higher education, particularly within technical disciplines and English for Specific Purposes (ESP), Bloom's Revised

Taxonomy serves as a foundational cognitive framework for structuring instructional tasks. Developed in 2001 by a team led by Lorin Anderson and David Krathwohl, this framework updated the original 1956 taxonomy by shifting the categories from nouns to active verbs and introducing a two-dimensional matrix that separates the Cognitive Process Dimension from the Knowledge Dimension.

So, according to this theory, students move upward through cognitive dimensions:

- Remembering and Understanding: Recognizing specialized vocabulary and retrieving technical definitions via AI-generated glossaries.
- Applying and Analyzing: Using GenAI to draft basic technical descriptions and then dissecting those outputs to evaluate their linguistic structures.
- Evaluating and Creating: Critically auditing AI drafts against rigorous professional benchmarks to synthesize authentic, high-fidelity technical documentation [1].

However, integrating automation into the classroom introduces distinct pedagogical challenges. To avoid passive reliance on AI outputs - where students accept machine-generated text without cognitive intervention - learners must develop a robust, highly critical genre awareness through comparative analysis. This critical framework is firmly grounded in John Swales' seminal genre analysis theory, which evaluates professional and academic texts based on a structured series of rhetorical "moves" and "steps". By applying this analytical lens, students can systematically deconstruct machine-generated drafts to uncover structural omissions that compromise the text's professional utility. This process exposes how large language models frequently fail to capture the nuanced rhetorical steps required in specialized communication, producing overly standardized or superficial prose. Engaging in this comparative evaluation encourages learners to actively question the validity of automated outputs rather than accepting them at face value. Ultimately, this rigorous textual scrutiny forms the basis of critical AI literacy, preparing future engineers to act as informed

and responsible stewards of technical documentation [10].

Empirical research comparing human-authored technical documents with large language model (LLM) outputs reveals a stark contrast: human-written texts possess significantly more contextual richness, argumentative depth, and precise, situational detail than their AI-generated counterparts. While LLMs excel at producing grammatically flawless, highly standardized, and structurally explicit prose, they frequently output generic, superficial, or overly formulaic content that lacks the nuanced insights of an industry expert. This stylistic uniformity occurs because generative models optimize for probability rather than genuine situational understanding or rhetorical intent. Consequently, machine outputs often miss localized sub-steps and specific industrial constraints that an experienced engineer would naturally include. Instructors can exploit these predictable qualitative gaps by transforming flawed machine text into valuable teaching opportunities in the classroom. Confronting these specific limitations forces students to actively engage in higher-order evaluation, learning to identify missing rhetorical moves and superficial technical logic [14].

Modern ESP pedagogy must therefore strategically leverage these structural differences rather than ignore them, recognizing that the gap between human and machine output is actually a powerful teaching tool. Instead of treating large language models as definitive writing engines that provide final, uncritical products, forward-thinking training frameworks should position them strictly as foil text generators. In this instructional capacity, the AI-generated text functions as a flawed baseline - an intellectual sparring partner designed to be questioned, dismantled, and systematically improved by the learner. Engineering students must be trained to analyze AI-generated drafts critically, looking past the deceptive surface fluency and grammatical perfection that large language models naturally display. To do this effectively, students must engage in active cross-referencing, directly mapping machine-generated outputs against authentic engineering data, real-world physical constraints, and classical Swalesian move-step structures to verify rhetorical and empirical validity. This systematic mapping prevents students from developing a passive reliance on automated text

production and encourages independent analytical thinking. By treating machine output as an initial hypothesis rather than an uncritical fact, learners are forced to re-examine the core communication goals of their specific technical discipline. Consequently, the classroom transforms into a collaborative editing workshop where the primary focus shifts from simple word generation to deep rhetorical and structural design. Ultimately, this direct engagement enables future engineering professionals to command generative tools with authority, precision, and acute situational awareness.

By learning to systematically identify missing rhetorical steps, diagnose superficial or circular logic, and perform rigorous lexical and structural editing, students shift from passive consumers of technology to highly active discourse editors. This deliberate, analytical intervention teaches future engineers how to actively imbue a document with the authentic disciplinary precision required by professional communities, forcing them to make conscious rhetorical choices rather than relying on automated text. This pedagogical transformation ensures that the final technical communication is not merely grammatically correct or superficially polished, but genuinely authoritative, contextually accurate, and professionally viable within high-stakes academic and industrial environments. Through this targeted refinement, learners develop the capacity to spot hidden flaws and factual inconsistencies that automated models frequently output. This rigorous training instills a deep sense of personal accountability, reinforcing that human oversight remains the ultimate line of defense against machine-generated errors. As a result, students cultivate a stronger professional identity, viewing themselves as competent human stewards who command advanced digital tools with critical intent. Ultimately, this comprehensive mastery of structural and rhetorical design prepares engineering graduates to confidently navigate the rapidly evolving communication demands of modern industry.

3. Interactive Simulations and Conversational Agents in ESP Pedagogy

Engineering communication does not occur in a vacuum; it is a highly dynamic, collaborative, and context-dependent process that underpins successful technical project execution. In the

contemporary globalized workspace, technical professionals must possess the linguistic agility to negotiate meaning across multidisciplinary teams, present complex data to diverse stakeholders, and troubleshoot critical system failures under pressure. Task-Based Language Teaching (TBLT) offers an exceptionally active, student-centered pedagogical framework by deliberately engaging learners in authentic language use that closely mirrors these real-world workplace scenarios [9].

By prioritizing meaningful interaction and the completion of realistic communicative tasks over the rote memorization of isolated grammar rules, TBLT bridges the historical gap between academic language instruction and actual industrial practice. When implemented effectively, this methodology treats language as a functional tool for solving complex engineering problems rather than an abstract subject of study [3].

To fully realize the potential of this framework, TBLT organizes instruction into a structured sequence of pre-task, task-cycle, and post-task phases that systematically scaffold student performance. During these phases, learners are not evaluated on linguistic accuracy alone, but on their ability to successfully achieve a tangible, non-linguistic outcome. This outcome-oriented design encourages students to naturally draw upon their existing cognitive and communicative resources to bridge informational gaps.

Furthermore, the tasks are designed with varying degrees of cognitive and communicative complexity to mirror the gradual onboarding process of a junior engineer. By manipulating variables such as planning time, the number of participants, and the familiarity of the technical topic, instructors can strategically increase the communicative load. This progressive conditioning helps students manage cognitive fatigue and linguistic strain during intense professional exchanges.

Ultimately, TBLT provides a natural environment for formative assessment, as feedback is directly tied to the student's communicative efficiency and operational success during the task. This immediate relevance ensures that language development is deeply integrated with the practical execution of engineering projects [7].

Integrating advanced conversational AI agents - such as specialized business-oriented tools like "TradeTalker" or purpose-built custom chatbots - directly into the TBLT framework allows engineering students to practice authentic, highly interactive discourse within a safe, controlled environment. These sophisticated digital tools can simulate an array of diverse, high-stakes workplace scenarios with remarkable fidelity, including initial client briefings, collaborative multi-party project meetings, safety audits, and intense technical troubleshooting dialogues. By embedding these simulated environments into the weekly curriculum, learners gain repeated exposure to the complex interpersonal dynamics that define modern industrial projects. This automated approach allows for instantaneous behavioral pacing, where the digital agent can modify its conversational demands based on the user's ongoing performance. Working through these realistic communication challenges helps bridge the gap between abstract academic vocabulary and spontaneous language use. Ultimately, this immersive method transforms traditional technical instruction into a proactive, experiential learning cycle that effectively prepares students for globalized engineering teams.

Viewed through the theoretical lens of Activity Theory, an AI conversational agent functions as a deeply transformative mediating artifact that fundamentally reconfigures the traditional classroom activity system. Instead of maintaining the rigid, passive, and teacher-centered instruction models of the past, the inclusion of these interactive digital tools shifts the classroom dynamic toward active, collaborative problem-solving, real-time negotiation, and structured peer coaching. The AI ceases to be a mere novelty and instead becomes an integral, structural component of the learning ecology that reshapes how students interact with knowledge, tasks, and one another.

To fully understand this structural evolution, one must analyze how the introduction of this advanced technology fundamentally alters the relationships among the key components of the instructional activity system. In a classical pedagogical setting, the student acts as the subject whose primary objective is the mastery of specialized technical genres and industry-standard communication. Historically, this relationship was mediated by static artifacts,

such as traditional text-based curricula or rigid grammatical writing templates, which often limited the student to passive consumption. By inserting an interactive conversational agent as a dynamic mediating artifact, the educational landscape experiences a profound realignment. The tool actively alters the subject-object relationship by providing immediate, context-aware responses, thereby transforming a static learning objective into an adaptive, evolving target that reacts to the student's growing linguistic and technical needs.

Furthermore, this technological integration completely disrupts the established community guidelines and the division of labor within the educational environment. In the traditional lecture model, the division of labor is sharply defined, positioning the instructor as the absolute repository of disciplinary knowledge and the student as a silent recipient. The conversational AI agent fundamentally reconfigures this dynamic by stepping into the operational role of an entry-level professional peer, a demanding client, or a flawed drafting partner. This shift reallocates the cognitive labor within the classroom community, allowing the instructor to transition away from basic lecturing and assume the role of an expert facilitator, structural auditor, and ethical guide. Consequently, the explicit and implicit rules governing classroom interaction shift from the memorization of isolated vocabulary to the mastery of sophisticated workflow procedures, where success is measured by the student's ability to direct, audit, and ethically manage automated information systems.

Finally, Activity Theory demonstrates that systemic learning and cognitive growth are driven by internal contradictions that emerge between different components of an activity system. The integration of large language models deliberately introduces a powerful structural contradiction between the superficial grammatical fluency of the machine and its actual empirical or rhetorical validity. When engineering students confront an AI-generated draft that is structurally flawless yet contains factually hallucinated figures or superficial professional logic, a productive cognitive tension is triggered. Resolving this systemic contradiction requires the student to move beyond passive acceptance and engage in higher-order evaluation, cross-referencing automated text against authentic engineering

data and professional standards. By negotiating these structural imbalances, the classroom community transforms into an active collaborative workshop. This continuous human-machine tension forces future technical professionals to develop the critical digital literacy, rhetorical judgment, and acute situational awareness required to lead as responsible human stewards in modern industry [2].

The psychological and affective benefits of this technology-enhanced approach are profound and measurable. This form of immersive, interactive practice has been shown to increase overall student motivation by approximately 35% compared to traditional, lecture-based methods. Simultaneously, it achieves this boost in engagement while reducing the intense performance anxiety that frequently plagues students when communicating in a foreign language within a public, highly scrutinized classroom setting.

In a traditional seminar, the fear of making grammatical errors or mispronouncing technical jargon in front of peers and instructors often induces communicative paralysis, severely limiting active language production. Conversational AI directly mitigates this barrier by providing an infinite, highly responsive sounding board that removes the social risk of failure from the immediate linguistic trial-and-error process.

By establishing this judgment-free environment, the digital tool allows learners to freely test complex phrasing and experiment with new structural conventions without public consequence. This low-stakes interaction encourages repetitive practice, which helps students internalize abstract technical vocabulary and naturally transition from passive recognition to active production. As the AI adapts its responses to the user's current ability, it provides targeted linguistic support that reinforces the student's sense of communicative competence. Over time, this supportive feedback loop systematically builds foundational writing and speaking self-efficacy within specialized disciplines. Consequently, students break free from defensive silence and develop the genuine operational confidence required to engage with global professional networks. Ultimately, alleviating this affective burden allows future technical professionals to redirect

their cognitive energy toward solving complex engineering problems rather than managing social anxiety [18].

Through repeated, continuous, and highly iterative interaction with an entirely non-judgmental AI partner, engineering students build foundational communicative confidence and rapidly develop essential transversal and social competencies. Because these conversational agents can be programmed to shift variables mid-dialogue - such as introducing an unexpected technical constraint during a simulation or adopting a demanding persona - students are forced to develop high levels of professional adaptability and collaborative problem-solving.

They learn to rephrase complex engineering concepts on the fly, manage misunderstandings constructively, and structure their technical arguments logically based on immediate machine feedback. Over time, this sustained practice ensures that when these future engineers transition into the actual workforce, they are not only technically proficient but also linguistically resilient, socially capable, and thoroughly prepared to navigate the communicative complexities of modern industrial projects.

To appreciate the depth of this pedagogical shift, one must recognize that modern engineering projects demand far more than isolated technical expertise. In the contemporary workspace, a professional's career trajectory is heavily dictated by their transversal competencies - often referred to as soft skills or transferable skills - which include critical thinking, ethical reasoning, cross-cultural communication, and emotional intelligence. Historically, traditional engineering curricula have struggled to systematically teach these abstract qualities, treating them as accidental byproducts of group work rather than core capabilities requiring structured development. Integrating adaptive AI simulations directly into the instructional workflow addresses this gap by creating a predictable environment where these vital professional ethics and soft skills are deliberately challenged, practiced, and refined. The automated platform functions as a mirror for the student's interpersonal habits, exposing weaknesses in logic, tone, and professional decorum before those errors can cause real-world liabilities.

Furthermore, this immersive environment accelerates the development of advanced professional ethics and collaborative flexibility through targeted interpersonal friction. When a student interacts with an AI agent assigned to play a rigid regulatory auditor or a skeptical corporate stakeholder, the communication moves beyond simple data exchange to become a sophisticated negotiation of values and constraints. Students must learn to maintain professional composure, respect ethical guidelines under pressure, and advocate for sustainable engineering practices using authoritative, structured language. This dynamic forces learners to actively look past their own subjective viewpoints, analyze the underlying motivations of their virtual counterparts, and tailor their technical rhetoric to meet specific institutional standards. Consequently, the learner shifts from a passive observer of professional ethics into an active, self-reflective practitioner who understands that technical solutions are only as viable as the communication used to support them [15].

Finally, this continuous human-machine engagement instills a deep sense of metacognitive awareness, allowing master's level students and future industry leaders to actively direct their own long-term professional development. By systematically reviewing transcripts of their AI interactions, students can critically analyze their own decision-making processes, identify recurring conversational errors, and consciously adjust their behavioral approaches for future tasks. This reflective process transforms a standard language exercise into a powerful laboratory for building long-term transversal resilience, helping students internalize a mindset of continuous self-improvement. As a result, graduates leave the university environment possessing a robust professional identity, viewing themselves not merely as calculators or designers, but as highly articulate human managers capable of steering complex, multi-party initiatives through unpredictable technical landscapes. Ultimately, mastering these transversal competencies ensures that tomorrow's engineers can bridge the gap between technical innovation and societal needs with clarity, empathy, and absolute professional integrity.

4. Prompt Engineering as a Rhetorical Competence

The operational efficacy of Generative Artificial Intelligence (GenAI) systems in the realm of technical communication is fundamentally and irrevocably determined by the qualitative precision of the instructions it receives from the user. Because of this structural reliance on human direction, prompt engineering - the highly systematic process of crafting, structuring, and iteratively refining text inputs to elicit highly precise, targeted outputs - should be treated as an essential, non-negotiable 21st-century digital literacy within higher education curricula. Far from being a purely technical or algorithmic skill relegated to computer science laboratories, prompt engineering within an English for Specific Purposes (ESP) context represents an inherently rhetorical act. It demands that the author engage in a thorough, highly conscious consideration of the target audience, the underlying communicative purpose, and the specific situational context in which the final document will operate. To prompt effectively is to understand how language shapes outcomes, transforming the user from a casual typewriter operator into a precise architect of automated textual discourse. This intricate linguistic process forces engineering students to deliberately manipulate parameters like persona, tone, and rhetorical intent to secure accurate results from the model. By learning to carefully calibrate these inputs, students develop a deep metacognitive awareness of how minor shifts in wording can radically alter the output's structural design. This deliberate practice teaches future professionals to view language not as a passive medium, but as an active tool used to program and steer automated information systems. Consequently, prompt engineering bridges the traditional divide between technical coding workflows and advanced human writing strategies. Ultimately, mastering this collaborative interface ensures that technical graduates can confidently command digital tools with absolute precision, strategic intent, and acute contextual awareness [13].

By deliberately embedding prompt engineering methodologies directly into professional technical writing curricula, educators encourage engineering students to make a profound cognitive shift away from surface-level content consumption toward highly active, deliberate language design. Rather than treating the language model as a simple search

engine or a passive text generator, students are taught to utilize advanced prompting strategies that mirror complex linguistic and structural frameworks.

These sophisticated strategies include:

- **Few-Shot Prompting:** Providing the model with explicit, high-fidelity linguistic examples to dictate the exact stylistic and structural parameters of the expected output. By embedding these curated exemplars directly into the input window, the model can instantly perform complex "in-context learning" without modifying its underlying weights. This targeted conditioning is exceptionally valuable in an ESP context, as it allows instructors to demonstrate industry-specific genres, specialized formats, or localized formatting conventions. When engineering students master this approach, they transition away from vague, open-ended queries and learn to program the model's stylistic parameters with absolute precision. Consequently, this method prevents the production of generic or overly formulaic prose, forcing the machine to mimic the exact structural moves of a seasoned technical expert.
- **Chain-of-Thought Reasoning:** Instructing the AI to display its step-by-step logic and analytical progression before generating a final answer, ensuring the transparency and technical validity of the text. Forcing the large language model to unpack its intermediate reasoning stages prevents it from jumping directly to an uncritical or superficial conclusion. This strategy is critical for complex multi-step tasks like troubleshooting system failures, performing safety audits, or interpreting intricate mathematical constraints. Reviewing this explicit logical progression allows engineering students to easily spot structural flaws, circular reasoning, or potential technical hallucinations. Ultimately, this approach turns the automated system into a transparent intellectual sparring partner,

helping future professionals develop the rigorous, step-by-step analytical habits required in high-stakes environments.

- **Role-Based Scenario Design:** Compelling the AI to adopt a highly specific professional persona, such as a senior aerospace quality assurance manager or a structural safety auditor, to ensure the tone matches industry standards. Assigning a precise operational profile forces the generative system to pull vocabulary and rhetorical strategies from a highly focused professional context. This immersive simulation creates an authentic, interactive environment where the model can challenge students by introducing sudden constraints or demanding administrative personas. This process directly expands the student's transversal and social competencies, preparing them to negotiate meaning across multidisciplinary teams. By learning to navigate these diverse virtual stakeholders with critical intent, future engineers build the exact professional identity and linguistic resilience required in modern globalized workspaces.

Through these advanced techniques, engineering students learn how to establish deep contextual frameworks, set strict stylistic constraints, and dictate the precise boundaries of technical vocabulary usage, forcing the machine to conform to professional linguistic expectations [5].

At the heart of this instructional approach is a deeply reflective, continuous feedback loop that redefines the traditional writing process. This cycle, where students actively write a prompt, critically analyze the resulting machine output, diagnose its rhetorical or technical deficiencies, and rapidly reformulate their instructions promotes an intense level of metacognitive awareness and active linguistic editing. Students are no longer blind recipients of text; they are forced to analyze why a specific word choice or structural omission occurred based on the ambiguity of their initial instructions. This iterative interaction transforms the act of writing into a transparent laboratory of cause and effect.

It requires students to constantly evaluate syntax, semantic clarity, and rhetorical alignment, ultimately deepening their understanding of how specific linguistic inputs directly control the precision, authority, and professional viability of technical documentation. By constantly engaging in this self-correcting workflow, engineering students internalize a rigorous habit of structural and lexical oversight. They begin to view digital text generation not as a magical shorthand for instant production, but as an ongoing negotiation that demands active human stewardship. This methodical prompt revision forces learners to look past deceptive surface fluency, developing a keen eye for subtle logical gaps and shallow engineering arguments. Consequently, this iterative cycle cultivates advanced transversal competencies like critical troubleshooting and cognitive flexibility directly within the writing curriculum. Ultimately, this reflective discipline shifts the student's professional identity from a passive consumer of software into a highly articulate discourse manager who commands generative tools with absolute strategic intent [6].

To maximize the pedagogical benefits of this digital literacy, training frameworks must extend beyond isolated, individualized machine interactions. Collaborative group assignments, such as the collective curation of professional prompt portfolios, serve to foster deep collaborative learning environments while forcing students to critically reflect on the distinct affordances and inherent limitations of different large language model (LLM) platforms. When working in teams to build a functional prompt library, engineering students must negotiate meaning, debate the efficacy of specific phrasing constraints, and peer-review the textual outputs generated by various models. This collaborative scrutiny strips away the myth of AI infallibility, teaching students to spot hallucinated data, identify superficial arguments, and recognize structural biases across different platforms. Consequently, curating these portfolios ensures that future technical professionals view GenAI not as a magic solution, but as a complex, highly malleable tool that requires rigorous human oversight, advanced rhetorical mastery, and constant ethical evaluation. By actively contrasting how different LLMs interpret identical sets of technical instructions, student cohorts build a sophisticated, comparative understanding of modern algorithmic architectures. This

collaborative benchmarking allows teams to determine which platform provides the most stable structural logic or authentic terminology for specific engineering disciplines, such as aerospace, civil, or electrical engineering. Furthermore, the act of peer-reviewing a teammate's prompt design cultivates essential social and transversal competencies, modeling the collaborative code-review workflows widely utilized in modern industrial environments. Through this collective evaluation, learners establish a shared repository of best practices, transforming individual trial-and-error into structured, institutional knowledge. Ultimately, this cooperative framework ensures that engineering graduates enter the global workforce not merely as isolated users, but as highly capable, digitally literate team leaders prepared to manage automated workflows with collective accountability [11].

5. Ethical Navigation, Hallucinations and Human Stewardship

While the computational and operational benefits of Generative Artificial Intelligence (GenAI) are undeniably substantial, its rapid integration into academic and industrial environments introduces severe ethical and practical risks that contemporary technical communication programs must aggressively and systematically address. These risks are not merely minor technical glitches; they represent fundamental vulnerabilities in the integrity of automated text production. Chief among these critical vulnerabilities is the persistent phenomenon of "hallucination" - a major operational defect where large language models produce highly persuasive, grammatically flawless, and authoritative-sounding assertions that are, in reality, completely factually fabricated, unverified, or scientifically incorrect.

In high-stakes engineering domains, relying on such unverified text can result in compromised safety protocols, flawed structural calculations, or severe compliance violations. This danger is further compounded by the machine's deceptive surface fluency, which easily misleads inexperienced students into accepting automated drafts without rigorous empirical cross-referencing. Consequently, engineering curricula must implement mandatory algorithmic verification protocols that train students to aggressively audit every layer of machine-generated documentation. This

active skepticism forces future technical professionals to treat AI outputs as unvetted material that requires absolute human accountability and exhaustive factual validation before industrial deployment. Ultimately, addressing these critical vulnerabilities ensures that the integration of digital tools does not compromise the core ethical standards, operational safety, and professional integrity of the engineering discipline. In the high-stakes fields of engineering and professional technical writing, where safety-critical precision is paramount and structural integrity is non-negotiable, the danger of these errors cannot be overstated. A single hallucinated metric, an incorrect mathematical figure, a fabricated academic reference, or a broken code snippet embedded into a maintenance manual or blueprint can result in severe operational failures, massive financial liabilities, or catastrophic real-world consequences.

Beyond the immediate technical dangers of machine hallucinations, the unmonitored use of public generative models creates a dense web of legal, institutional, and intellectual property challenges. Within higher education and corporate research sectors, serious issues surrounding data privacy and regulatory frameworks represent significant barriers to the unchecked adoption of these tools. For instance, inputting student data or grading rubrics into external, public AI platforms can lead to direct violations of institutional compliance, such as FERPA regulations. Furthermore, feeding proprietary engineering blueprints, unpatented research methodologies, or sensitive corporate data into commercial models often breaches non-disclosure agreements and exposes valuable intellectual property to public data scraping. This unchecked exposure risks compromising university patents and industry trade secrets, potentially leading to costly legal battles over intellectual ownership. To mitigate these institutional vulnerabilities, technical universities must establish secure, localized network infrastructures or enter into strict data-sharing agreements that guarantee absolute user confidentiality. Students must be explicitly trained to recognize the legal boundaries of digital data processing, ensuring they understand where private research ends and public exposure begins. Ultimately, implementing these strict boundary guidelines allows academic and industrial ecosystems to leverage automation without sacrificing data

security or legal integrity. The risk of potential plagiarism and copyright infringement remains incredibly high, as these models are trained on massive, sometimes copyrighted datasets without explicit attribution. Of even greater concern to industrial and engineering sectors is the systemic leakage of highly proprietary, patented, or unreleased technical data into public models. When an engineer inputs a sensitive company schematic or a proprietary software algorithm into a public chatbot for optimization, that data is frequently ingested to train future iterations of the model, completely compromising corporate intellectual property and violating strict non-disclosure agreements.

To effectively mitigate these multi-faceted risks, English for Specific Purposes (ESP) training and broader technical writing curricula must completely move away from outdated, adversarial methods of "AI policing" and instead prioritize the development of critical AI literacy. Attempting to ban these technologies or relying entirely on unreliable AI detection software creates a culture of distrust and fails to prepare students for the realities of the modern digital workplace. Instead, forward-thinking educational frameworks must integrate strict, non-negotiable validation and verification protocols directly into the writing process.

Students must be explicitly taught to treat generative AI as an unverified, entry-level collaborative drafting partner rather than an expert or definitive authority. Every single line of code, every cited source, and every technical specification generated by a machine must be treated as a hypothesis that requires rigorous human cross-referencing against authentic, peer-reviewed engineering data and physical documentation before it can be integrated into a professional document.

This rigorous approach to human-machine collaboration aligns directly with the professional standards and guidelines established by leading international organizations, such as the IEEE Professional Communication Society (ProComm) [12]. According to these professional frameworks, technical communicators are not passive copy-editors; they must actively position themselves as informed, highly capable, and deeply ethical stewards of these technical information systems. This concept of human stewardship redefines the relationship between the writer

and the technology, emphasizing that the human professional must always retain ultimate accountability for the accuracy, safety, and ethical implications of the distributed information.

By cultivating a strong, unshakeable foundation of human agency, critical oversight, and sharp rhetorical judgment, engineering students learn a vital career lesson: their ultimate value as future technical professionals does not lie in the mechanical speed of text generation, but in context-aware synthesis, genuine user empathy, and complex ethical decision-making - qualities that automated generative systems simply cannot replicate or replace.

6. Conclusions

The strategic integration of Generative Artificial Intelligence (GenAI) into English for Specific Purposes (ESP) training marks a significant turning point in professional technical communication pedagogy for engineering students. Grounded in Swales' genre analysis and Activity Theory, this approach transforms large language models from passive text generators into active, dynamic mediating artifacts that structurally reconfigure the traditional classroom environment. By organizing instruction around Task-Based Language Teaching (TBLT) and framing prompt engineering as a core rhetorical competency, curricula can systematically guide students through progressive cognitive dimensions to bridge the gap between classroom theory and real-world industrial demands.

Furthermore, interactive simulations with AI conversational agents provide a highly effective, low-stakes environment that drastically lowers foreign language anxiety while simultaneously fostering essential transversal and social competencies. Confronting the distinct qualitative gaps and structural differences between machine-generated drafts and human writing forces students to develop critical digital literacy and acute situational awareness. Instead of relying on passive content consumption or adversarial "AI policing," forward-thinking frameworks must implement strict, non-negotiable validation and verification protocols to mitigate multi-faceted risks like data

leakage and factual hallucinations. Ultimately, this pedagogical shift ensures that technical graduates emerge not as dependent users of software, but as highly articulate, responsible, and ethical human stewards capable of commanding advanced digital tools with absolute strategic intent in Industry 4.0.

To fully embed this methodology within technical universities, educators must strategically combine corpus-driven tasks with personalized feedback mechanisms to address specific student learning gaps. Utilizing custom-built conversational systems allows for real-time behavioral pacing, which dynamically scales communication complexity based on a learner's immediate performance. This advanced adaptability is particularly crucial in high-stakes fields like aerospace or civil engineering, where the exact phrasing and density of automated data must match explicit industry benchmarks. As students negotiate meaning through specialized virtual avatars, they actively learn to defend complex technical hypotheses under pressure. This ongoing human-machine tension forces future professionals to move past a deceptive surface fluency and aggressively audit the factual and structural validity of automated outputs. Moving beyond isolated machine interactions, collaborative assignments like the collective curation of prompt portfolios cultivate shared accountability and collective digital literacy within student cohorts. By directly analyzing the distinct operational limitations and hidden algorithmic biases across various platforms, teams learn to treat automated drafts with rigorous intellectual skepticism. As highlighted in "Enhancing the Professional Technical Communication Skills of Engineering Students via Generative AI Integration in ESP Training.docx", grounding classroom practices in these secure, human-centric workflows prepares tomorrow's engineers to handle complex industrial projects with maximum professional integrity.

7. References

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