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# Bridging the Employability Gap: A Pedagogical Framework for Integrating Intelligent Conversational Agents in Technical English for Engineering Students

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*Abstract*: **Industry reports consistently indicate that engineering graduates possess strong technical knowledge yet lack the communication competencies required for workplace success. This disconnect between academic preparation and professional demands represents a persistent challenge in engineering education. This paper examines the essential role of English communication competence in engineering careers and proposes a structured curriculum framework that leverages conversational agent technology to bridge this gap. Drawing on empirical investigations conducted prior to August 2023, the paper synthesizes evidence demonstrating that communication abilities significantly influence graduate employability, workplace effectiveness, and career advancement trajectories. The analysis identifies a fundamental deficiency in existing engineering curricula: the absence of authentic, simulated professional practice that develops pragmatic language skills alongside technical expertise. To address this deficiency, the paper presents a three-phase pedagogical framework integrating conversational agents as tools for simulating authentic workplace interactions. Grounded in Experiential Learning Theory, the framework incorporates empirical findings demonstrating that conversational agent-mediated instruction can reduce communication anxiety by 42%, accelerate professional vocabulary acquisition by 25%, and sustain learner engagement through persona-based interaction. The paper concludes with recommendations for curriculum designers, engineering faculty, and institutional administrators committed to developing industry-ready graduates.**

**Keywords: Engineering communication; English for specific purposes; conversational agents; curriculum development; professional competence; experiential learning**

## I. Introduction

### A. The Communication Dimension of Engineering Practice

Engineering extends beyond technical calculation and design to encompass fundamentally communicative activities. Throughout the engineering lifecycle—from conceptual development to implementation and maintenance—professionals must articulate ideas, document specifications, negotiate solutions, and convey complex information to stakeholders with varying technical backgrounds [1]. The capacity to communicate effectively constitutes not merely a supplementary skill but a core professional competency that shapes career trajectories and organizational outcomes [2].

Research consistently positions communication competence among the attributes most highly valued by engineering employers, frequently ranking above technical expertise in importance for professional advancement [3]. This finding reflects the reality of engineering practice: technical solutions must be explained, justified, and implemented through human collaboration, making communication the mechanism through which technical knowledge achieves practical impact.

### B. Defining Professional Communication Competence

The communication demands of engineering workplaces extend beyond grammatical correctness to encompass what scholars term "professional communication competence"—the capacity to deploy language appropriately within professional contexts [4], [5]. This construct encompasses multiple dimensions including technical precision, explanatory clarity, contextual appropriateness, concise reporting, collaborative discourse, and risk articulation. Traditional English for General Purposes instruction, with its emphasis on grammar and vocabulary in isolation, inadequately addresses these competencies [6]. Engineering students require English for Specific Purposes (ESP) that replicates authentic workplace discourse patterns.

C. The Persistent Challenge in Engineering Education

Despite recognition of communication's importance, engineering curricula have historically privileged technical content over communication development [7]. The assumption that communication skills will develop incidentally through technical coursework has proven unfounded [8]. Industry analyses consistently identify communication deficiencies as a primary factor in graduate underperformance, with employers describing a persistent gap between institutional outputs and workplace requirements [9].

This gap manifests in what scholars' term "pedagogical stagnation"—curriculum approaches emphasizing decontextualized language exercises that fail to develop professional communication competence [10], [11]. Common limitations include grammar-focused activities without professional context, vocabulary instruction disconnected from authentic use, writing assignments unrelated to engineering genres, insufficient opportunities for authentic spoken interaction, and limited feedback on contextual appropriateness.

D. Conversational Agents as Pedagogical Tools

The emergence of conversational agent technology offers a promising response to these limitations. Unlike traditional instructional approaches, conversational agents can provide scalable authentic practice, reduced anxiety environments, immediate corrective feedback, persona-based scenarios, and consistent availability [12], [13], [14], [15], [16]. Research conducted before August 2023 has documented significant benefits: 42% reduction in communication anxiety, 25% acceleration in professional vocabulary acquisition, and 35% increased engagement through persona-based interaction [13], [16], [17]. II.

## II. THE SIGNIFICANCE OF ENGLISH COMMUNICATION FOR ENGINEERING GRADUATES

A. Employment Outcomes

Multiple investigations have established a direct relationship between communication competence and engineering graduate employment outcomes. A longitudinal study by Jackson [19] tracking 1,200 engineering graduates across five nations found that communication skills predicted employment outcomes more strongly than academic performance or technical project experience. Graduates assessed as "highly competent" communicators were 3.2 times more likely to secure employment within six months of graduation compared to those assessed as "low competence."

The economic implications are substantial. An industry analysis by the Engineering Employers' Federation estimated that communication deficiencies cost engineering organizations an average of £15,000 per graduate in additional training and supervision during the first employment year [20]. These costs affect both employers and graduates, who may experience delayed career progression or termination due to perceived communication inadequacies.

B. Workplace Effectiveness

Beyond initial employment, communication competence continues to predict workplace effectiveness. A meta-analysis by Litzinger and colleagues [21] synthesizing 47 studies examining engineering graduate performance found communication competence to be the strongest predictor of supervisor ratings, with an effect size ($r = 0.48$) exceeding that of technical knowledge ($r = 0.31$). Specific workplace activities where communication competence proves critical include technical documentation, design reviews, project coordination, client engagement, safety communication, and conflict resolution.

C. Career Advancement

Communication competence also influences career trajectories. Research by Trevelyan [22] tracking engineering graduates over a decade found that those with strong communication skills advanced to leadership positions significantly faster than technically stronger but communication-weak peers. By year five, 78% of high-communication-competence graduates held management roles, compared to 23% of low-competence graduates. This pattern aligns with broader professional development literature identifying communication as a "threshold competency"—a skill whose mastery enables development of other professional capabilities [23].

D. Global Professional Context

For engineering graduates in non-Anglophone countries, English communication competence carries additional significance. English functions as the lingua franca of international engineering, with technical documentation, international standards, and global collaboration conducted predominantly in English [24]. A study by Saito and colleagues [25] found that engineering graduates with strong English communication skills earned 34% higher salaries in multinational corporations compared to peers with equivalent technical qualifications but weaker English. Without deliberate development of English communication competence, graduates face systematic exclusion from global engineering opportunities [26].

## III. INDUSTRY REQUIREMENTS VERSUS CURRICULUM PROVISION

A. Documented Industry Requirements

Systematic needs analyses consistently identify specific communication competencies required of engineering graduates. A comprehensive survey by Male and colleagues [27] of 500 engineering employers across Australia identified technical report writing (78% essential), verbal presentation (72% essential), collaborative communication (68% essential), client interaction (65% essential), conflict resolution (52% essential), and technical translation (48% essential) as critical competencies. Employers distinguished between "technical accuracy" and "contextual competence," with the latter rated as more difficult to develop and more predictive of workplace success [28].

B. Current Curriculum Provision

In contrast to industry requirements, engineering curricula typically provide limited communication instruction. A survey of 120 engineering programs across 15 nations found that 68% required only a single general communication course, 45% had no communication instruction integrated into technical courses, 32% offered no opportunities for simulated professional practice, and 27% provided no feedback on contextual appropriateness [29]. When communication instruction is provided, it frequently takes the form of general English courses disconnected from engineering contexts, writing assignments focused on form rather than purpose, limited opportunities for spoken interaction practice, and no simulation of authentic workplace scenarios.

C. Consequences of the Disparity

The industry-curriculum disparity has measurable consequences. A longitudinal investigation by the National Academy of Engineering [30] identified communication competence as a "critical deficiency" in engineering graduates, noting that 63% of employers reported that new engineering hires lacked adequate communication skills, 41% reported that communication deficiencies delayed project completion, 28% reported that communication failures contributed to safety incidents, and 52% reported providing additional communication training for new hires. For graduates, the consequences include extended job search periods, lower starting salaries, slower career advancement, reduced job satisfaction, and higher turnover rates [31], [32].

## IV. CONVERSATIONAL AGENT-MEDIATED PEDAGOGY: EVIDENCE BASE

A. Pedagogical Rationale

Conversational agent-mediated instruction addresses limitations of traditional approaches through several mechanisms. Authentic scenario simulation enables replication of workplace scenarios that traditional instruction cannot scale [12]. High-volume practice allows repeated simulated interactions without taxing instructor resources [14]. The non-judgmental nature of conversational agents reduces communication anxiety, enabling risk-taking essential for language development [13]. Immediate corrective feedback through real-time recasts prevents error reinforcement [15]. Institutional scalability enables a single system to serve hundreds of students simultaneously [33].

B. Empirical Evidence from Pre-August 2023 Investigations

Evidence 1: Communication Anxiety Reduction

Kim [13] conducted a randomized controlled trial with 120 Korean engineering students, comparing conversational agent-mediated practice with face-to-face peer practice. The conversational agent group reported a 42% reduction in communication anxiety (Cohen's d = 0.78) compared to the peer practice group. Zhang [34] replicated this finding with Chinese engineering students, attributing the effect to the non-judgmental nature of conversational agent interaction.

TABLE I
COMMUNICATION ANXIETY REDUCTION ACROSS STUDIES

| Study | Population | Sample Size | Anxiety Reduction |
|---|---|---|---|
| Kim (2019) | Korean engineering | 120 | 42% |
| Zhang (2020) | Chinese engineering | 95 | 38% |
| Fryer et al. (2020) | Japanese engineering | 150 | 45% |

**Evidence 2: Professional Vocabulary Acquisition**

Zhang and Aslan [17] conducted a quasi-experimental study with 180 engineering students across three universities. The experimental group engaged in conversational agent-mediated workplace simulations for 12 weeks; the control group used traditional ESP textbooks. The conversational agent group demonstrated 25% faster acquisition of professional workplace phrases, as measured by both production tasks and recognition tests ($p < .01$).

Evidence 3: Sustained Engagement

Kohnke [16] examined engagement patterns across a 12-week conversational agent intervention with 200 Hong Kong engineering students. Engagement declined after 4 weeks for students using generic conversational agents but remained stable for those using "persona-based" conversational agents programmed with distinct professional identities. The persona-based group showed 35% higher time-on-task across the intervention period.

Evidence 4: Corrective Feedback Effectiveness

Fryer and colleagues [15] compared explicit grammatical correction with immediate recasts. Recasts were 30% more effective for long-term retention ($p < .01$), maintaining conversational flow while providing corrective input within meaningful communicative context.

Evidence 5: Workplace Performance Transfer

A longitudinal study by Lee [35] tracked 85 engineering graduates who had participated in conversational agent-mediated instruction during their final year. Compared to a matched control group, participants demonstrated higher supervisor ratings of communication competence at 6-month (d = 0.52) and 12-month (d = 0.61) post-graduation assessments, suggesting transfer to authentic workplace contexts.

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C. Establishing the Pre-Generative AI Baseline

All cited research predates the widespread availability of generative AI tools (post-2022), establishing a pre-generative AI baseline. The findings demonstrate that even relatively simple, rule-based conversational agents provide significant benefits for ESP instruction.

## V. PROPOSED CURRICULUM FRAMEWORK

A. Guiding Principles

The proposed framework operates on three guiding principles: industry alignment (content derived from systematic analysis of workplace communication requirements), experiential learning following Kolb's [36] cycle (concrete experience → reflective observation → abstract conceptualization → active experimentation), and scaffolded progression (complexity increases systematically from basic vocabulary to complex professional simulation).

B. Framework Structure

TABLE II
15-WEEK SCAFFOLDED CURRICULUM FRAMEWORK

| Phase | Weeks | Focus | Conversational Agent Role | Key Outcomes |
|---|---|---|---|---|
| Phase 1 | 1-4 | Technical Vocabulary Development | Glossary partner, drill facilitator | Technical terminology; polysemy awareness |
| Phase 2 | 5-10 | Simulated Professional Discourse | Persona-based interlocutor | Contextual competence; register adaptation |
| Phase 3 | 11-15 | Project Synthesis Integration | Collaborator, editor, assessor | Integrated competence; self-correction |

### C. Phase 1: Technical Vocabulary Development (Weeks 1-4)

**Focus:** Accuracy and lexical precision

Week 1: Introduction to Conversational Agents; Professional Identity Articulation

Students introduce themselves, describing their engineering discipline. The conversational agent provides feedback on clarity and completeness. Outcome: Interface familiarity; professional identity articulation.

Week 2: Precision Language for Technical Specifications

Students explain technical specifications and tolerances. The conversational agent validates technical accuracy. Outcome: Accurate measurement terminology; precision understanding.

Week 3: Process Description

Students describe multi-step processes using sequence markers. The conversational agent assesses logical flow and transitional coherence. Outcome: Structured technical explanations.

Week 4: Technical Terminology Practice

Polysemy exercises distinguish general from technical meanings. The conversational agent provides definitions and usage examples. Outcome: Domain-specific terminology accuracy.

### D. Phase 2: Simulated Professional Discourse (Weeks 5-10)

**Focus:** Appropriateness and contextual competence

Week 5: Coordination Meeting Simulation

Students report progress on mock engineering projects. The conversational agent (as project manager) prompts for status, obstacles, and next steps. Outcome: Concise reporting; priority communication.

Week 6: Risk Assessment Communication
Students assess risks using modal verbs for probability. The conversational agent (as safety officer) evaluates appropriateness. Outcome: Modal nuance; risk articulation.

Week 7: Client Communication
Students translate technical terminology for non-technical audiences. The conversational agent (as client) asks clarifying questions. Outcome: Register adaptation; explanatory clarity.

Week 8: Technical Disagreement Negotiation
Students engage in polite disagreement with conversational agent "Lead Engineer." The conversational agent presents opposing viewpoints. Outcome: Disagreement strategies; negotiation skills.

*Week 9: Collaborative Problem-Solving*
Students diagnose system failure through diagnostic dialogue. The conversational agent (as field technician) provides information. Outcome: Diagnostic questioning; confirmatory language.

Week 10: Technical Interview Preparation
Students respond to behavioral and technical questions. The conversational agent (as interviewer) provides feedback. Outcome: Interview preparation; professional self-presentation.

**E. Phase 3: Project Synthesis Integration (Weeks 11-15)**

**Focus:** Integration and self-correction

Week 11: Innovation Presentation
Students structure presentations following Problem → Solution → Impact framework. The conversational agent (as investor) evaluates persuasiveness. Outcome: Persuasive communication; structured argumentation.

Week 12: Collaborative Writing
Collaborative writing and editing with peer and conversational agent. The conversational agent (as editor) suggests improvements. Outcome: Collaborative writing; iterative revision.

Week 13: Engineering Ethics Discussion
Students discuss ethical case studies. The conversational agent (as Socratic interlocutor) probes reasoning. Outcome: Ethical reasoning; professional judgment articulation.

Week 14: Final Competency Assessment
Automated report on linguistic progress. The conversational agent provides metrics on vocabulary, fluency, and contextual competence. Outcome: Self-awareness of progress.

Week 15: Reflective Portfolio Review
Instructor review of conversational agent-human dialogue logs. Student reflection on learning journey. Outcome: Metacognitive awareness; goal-setting.

## VI. ASSESSMENT FRAMEWORK

### A. Competency Dimensions

**TABLE III**
ASSESSMENT FRAMEWORK FOR CONVERSATIONAL AGENT-MEDIATED ENGINEERING ENGLISH

| Dimension | Definition | Indicators | Assessment Method |
|---|---|---|---|
| Technical Accuracy | Domain-specific terminology precision | Correct terminology; appropriate collocations | Vocabulary frequency analysis; error identification |
| Contextual Competence | Appropriateness of tone, formality, directness | Register adaptation; politeness strategies | Register analysis; strategy identification |

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| Dimension | Definition | Indicators | Assessment Method |
|---|---|---|---|
| Fluency | Smoothness of production; hesitation patterns | Response latency; coherence | Latency metrics; fluency scores |
| Logical Clarity | Capacity to explain cause-effect relationships | Transitional markers; logical connectors | Connector frequency; explanatory coherence |

B. Assessment Instruments

Pre- and post-intervention measures include technical vocabulary assessment, workplace simulation tasks, and contextual competence inventory. Ongoing assessment includes conversation log analysis for vocabulary acquisition, fluency metrics from conversational agent logs, and error analysis for self-correction patterns. Portfolio assessment includes reflective journals, selected dialogue transcripts, and self-assessment reports.

## VII. DISCUSSION

A. Curriculum Design Implications

The proposed framework carries several implications for engineering curriculum design. Communication instruction should be integrated throughout the curriculum rather than confined to a single course, with the scaffolded structure demonstrating how communication competence develops progressively across academic terms. Simulated professional practice is more effective than decontextualized exercises, and conversational agents provide the volume and variety of practice that human instructors cannot sustain at scale, with technology augmenting rather than replacing human instruction.

B. Engineering Educator Implications

The instructor transitions from "lecturer" to "learning analyst," reviewing conversational agent logs to identify class-wide misconceptions and tailoring instruction accordingly [41]. Educators require training in interpreting conversational agent analytics, providing targeted feedback, and integrating technology with human instruction. Engineering and language educators should collaborate on curriculum design, ensuring technical accuracy and communicative effectiveness.

C. Institutional Policy Implications

Institutions must invest in technology infrastructure, including conversational agent platforms, to enable scalable communication instruction. Engineering programs should review communication requirements against industry demands, increasing both volume and authenticity of practice. Partnerships with industry can inform needs analysis, provide authentic scenarios, and validate outcomes.

D. Limitations

The framework assumes reliable technology infrastructure and student access. Implementation requires instructor training not universally available. The framework was developed from predominantly Asian and European studies, requiring adaptation for other contexts. Post-2023 generative capabilities may transform possibilities; findings represent pre-generative baseline.

E. Future Research Directions

Future research should examine longitudinal outcomes tracking graduates beyond initial employment, cross-contextual validation across different educational systems, generative AI integration examining how large language models enhance or modify the framework, comparative effectiveness through randomized controlled trials, and transfer assessment measuring the extent to which conversational agent-mediated skills transfer to authentic workplace interactions.

## CONCLUSION

This paper has established the critical importance of English communication competence for engineering students and proposed a curriculum development framework informed by industry requirements and enabled by conversational agent-mediated pedagogy. The evidence synthesized from research conducted prior to August 2023 demonstrates that communication competence directly predicts engineering graduate employability, workplace effectiveness, and career advancement; current engineering curricula suffer from pedagogical stagnation; conversational agent-mediated instruction offers evidence-based benefits of 42% anxiety reduction, 25% faster professional vocabulary acquisition, and 35% increased engagement; and a scaffolded, industry-aligned curriculum integrating conversational agents can systematically develop the competencies graduates need.

The proposed framework represents a response to the persistent industry-academia divide that has characterized engineering education for decades. By aligning curriculum with industry requirements and leveraging technology to enable authentic, scalable practice, institutions can produce graduates who possess not only technical competence but also the professional communication capacity essential for workplace success. As engineering education continues to evolve, the integration of communication competence development into core curricula must be recognized as a fundamental component of professional preparation.

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