An incremental model for professional language training in a digital educational environment

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Abstract

The paper presents the theoretical justification and experimental implementation of an incremental model designed to enhance professional foreign language training in the digital educational environment of a technical university. The study is conducted in the broader context of education digitalization and the increasing demand for flexible, step-by-step learning models that align with the specific communicative needs of engineering students. Emphasizing the structured development of four key skills – cooperation, critical thinking, creativity, and professional communication – the model integrates pedagogical principles and methods relevant to 21st-century challenges. The incremental model consists of four successive stages, each corresponding to a year of undergraduate study, and is characterized by its spiral structure that facilitates consistent skill accumulation and increasing linguistic complexity. The implementation relies on effective pedagogical strategies, including project-based learning, dialogic methods, problem-solving tasks, brainstorming sessions, work with technical texts, language quests, and project defense formats. These methods and formats supported dynamic, student-centred training and facilitated the integration of linguistic content with domain-specific professional communication. Empirical data demonstrate a steady improvement across all indicators, confirming the effectiveness of the model in facilitating language acquisition through contextually grounded, discipline-oriented content. The article also outlines the methodological tools applied in the study, including comparative analysis, modelling, and pedagogical observation, which enable the identification of systemic factors influencing language training outcomes. The findings indicate that a gradual, resource-supported approach to language training more effectively accommodates the learning trajectories of students while fostering motivation, adaptability, and linguistic autonomy. These findings contribute to the ongoing discourse on flexible digital pedagogies and provide a scalable model for integration into modern technical education.

Keywords

professional language training, digital educational environment, information and educational environment, soft skills, incremental model

1. Introduction

In the context of advancing educational digitalization and increasing demands for professional foreign language training of future engineering specialists, the need for flexible and adaptive methodological solutions becomes particularly relevant. Language learning is a complex process encompassing phonetic, lexical, grammatical, discursive, and pragmatic components that should work together as part of a single system. Proficiency in a foreign language requires students to acquire specific skills, including analytical reading, clear oral and written expression of professional ideas, technical translation skills, and participation in intercultural dialogue.

In the digital age, language education is undergoing profound transformation: not only is the format of content delivery changing, but also the very logic of linguistic interaction, which is increasingly

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mediated through digital services, platforms, and mobile applications. At the same time, adaptive learning tools are gaining importance, as they accommodate individual cognitive styles and learning paces. Foreign language training is not an exception; on the contrary, it reinforces the broader trend toward the professionalization of education, especially in response to the demands of the 21st century. This complexity requires the use of step-by-step approaches to language proficiency development, which account for individual learning trajectories and enable the flexible adaptation of instructional tasks to changing educational contexts [1, 2, 3, 4].

The search for effective models capable of facilitating a gradual, flexible, and technologically grounded transition to high-quality professional foreign language training is gaining increasing relevance in the context of educational digitalisation. The information and educational environment of a technical university is characterised by a strong engineering focus, the integration of digital platforms and technologies, and a predominance of practice-oriented learning formats. Under such conditions, the integration of language training with professional communication, adapted to digital formats and the specific demands of the technical domain, becomes particularly significant.

In response to these challenges, an incremental model has been developed, serving as the theoretical and practical foundation for a methodology of professional language training within the digital environment of a technical university. Its conceptual framework is grounded in the principles of systematisation, phased progression, adaptability, and functional relevance, enabling it to respond to current trends in digitalisation as well as to the individual trajectories of students' professional development [2, 5].

In contemporary educational practice, the notion of "increment", which is derived from the Latin "incrementum" and means the growth or gradual increase, refers to the phased expansion or development of the learning process that has acquired particular relevance in the context of digital transformation.

As a principle, incrementality was first introduced in the field of software development in the second half of the 20th century, particularly in Barry Boehm's research. Within the evolutionary approach to complex system design, Boehm introduced the concept of gradual functionality enhancement. In his influential paper "A Spiral Model of Software Development and Enhancement", he elaborated on the application of incrementality as a methodology for software development. Subsequently, the key elements of this approach were adapted to the field of education, especially in the design of staged training content [6].

The incremental model involves a logically structured sequence of training, where each stage is built on the achievements of the previous one. This approach supports individual learning trajectories, facilitates the progressive introduction of increasingly complex content and tasks, and ensures the flexibility and adaptability of the training process in response to changing professional and digital environments. The concept has an interdisciplinary foundation and is actively employed in pedagogy (M. Clarke, R. Snow, S. Helme, I. Hrom), systems theory (L. von Bertalanffy, J. Forrester), and information technology (B. Boehm, K. Beck) [7].

In pedagogy, the principle of incrementality is reflected in the gradual formation of knowledge and skills in accordance with the principles of constructivism. This approach allows the training process to be adapted to the students' prior knowledge and ensures the consistency of learning outcomes. In particular, incrementality contributes to the effective combination of theory and practice, which is especially valuable in the context of the dynamic development of digital educational technologies.

Several researchers have contributed to the understanding of incrementality in the educational field. M. Clarke, in his research on the acmeological development of teaching expertise, described the incremental acquisition of professional skill through experience accumulation. Another foreign scientist, R. Snow explored the incremental instructional strategies in relation to students' individual cognitive styles. S. Helme applied phased complexity in STEM education, while I. Hrom described incrementality as a mechanism for achieving educational outcomes within digital environments. Thus, incrementality in pedagogy is regarded as an effective means of structuring the learning process, allowing for progressive content complexity, adaptation to personalised learning pathways, and sustained development of professional readiness within dynamic educational contexts [7, 8, 9, 10].

In the modern information and educational environment of technical universities, the effectiveness of professional language training greatly depends on the level of implementation of innovative edu-

cational technologies based on conceptual foundations, pedagogical principles, training theories, and methodological approaches. To substantiate the incremental model of professional language training methodology, it was necessary to analyse the system-forming characteristics of the digital educational space of a technical university and identify the patterns of developing foreign language communication skills among future engineering specialists. These patterns reflect the connection between the demand of a multicultural digital society for communication-competent specialists and the functioning of professional language training as an integrated component of the holistic educational process. It performs educational, training, and developmental functions based on the didactic principles of openness, dynamism, interactivity, systematicity, and practical orientation.

The methodological basis of the study comprised:

- Comparative analysis, which enabled the comparison of approaches to language training in digital learning environments and allowed the identification of effective practices for integrating professional and language components;
- Pedagogical observation, involving the systematic study of the dynamics of students' language behaviour, communicative activity, and responses to various methodological influences in the real conditions of the educational process;
- Modeling, which made it possible to reproduce the structure and mechanisms of professional language training in the conditions of digitalization, as well as to create an incremental model as a synthesis of analytical and experimental findings.

The integrated application of these methods ensured the scientific validity of the proposed model and its adaptation to the specifics of the information and educational environment of a technical university.

2. Implementation and validation of the incremental model for professional foreign language training

Based on the methodological foundation of this study, it was hypothesised that an incremental model would be effective for organising professional foreign language training for future engineers. This model improves a systematic and sequential development of language skills, taking into account the inherent complexity and multi-level structure of language acquisition. Its potential lies in supporting learners' progression through a logical transition from basic to more complex material, while maintaining the flexibility necessary to accommodate individual learning trajectories.

The incremental model is grounded in the development of core skills aligned with contemporary educational paradigms, mainly 4Cs – critical thinking, creativity, communication, and collaboration – which are regarded as essential for the effective integration of engineering professionals into multilingual and multicultural work environments. These 21st-century skills form a critical foundation of professional readiness for future engineers [11], fostering the ability to work effectively in multifunctional teams, adapt to dynamic digital settings, engage critically with complex information flows, and devise efficient engineering solutions.

- Critical thinking supports accurate interpretation of technical data, discourages reliance on formulaic solutions, and encourages source verification;
- Creativity encourages the generation of original ideas and the development of innovative approaches to professional challenges;
- Communication underpins interdisciplinary interaction, especially in English-medium professional contexts;
- Collaboration (cooperation, cooperative engagement) ensures coordinated teamwork and exchange of knowledge while working on joint technical projects.

Consequently, the cultivation of these skills should be viewed not as an supplementary element, but as a key component of professional language training for engineering students in the context of the ongoing digital transformation of higher education [8, 12].

Mastering a foreign language for professional purposes requires a well-structured curriculum, in accordance with students' learning trajectories, and the gradual development of communicative skills. The incremental model effectively supports this process by ensuring a structured delivery of content that follows a consistent trajectory of increasing complexity, thereby avoiding fragmentation and supporting sustainable learning outcomes. English, in particular, possesses a complex internal structure comprising phonetic, grammatical, lexical, syntactic, and pragmatic layers that operate interdependently. Language acquisition cannot occur instantaneously; only a step-by-step approach allows learners to internalise both the rules and the underlying logic of language construction.

For instance, the system of grammatical tenses must be introduced in a specific order, beginning with present simple forms and advancing through conditionals and sequence of tenses, eventually incorporating active and passive voice constructions. Mastery of these elements requires time, repetition, and contextual reinforcement, particularly in professional language use. Special attention must also be given to fixed expressions and syntactic patterns that are characteristic of technical discourse, such as those used to describe diagrams, technical equipment, operating procedures, and functional specifications. The incremental model addresses these needs by organising language content into successive stages, progressing from basic structures to complex communicative tasks embedded in professional scenarios. As a result, the learning process becomes coherent, and the acquired language skills are directly applicable to real-world professional interactions [13, 14].

The model further promotes adaptability, durable learning outcomes, and digital integration – all of which are essential for effective education in technical universities. Furthermore, it supports learner autonomy in developing professional foreign language competence by integrating digital tools familiar to modern students.

Moreover, the applied logic of the incremental approach is conceptually aligned with the principle of versioning, which is commonly used in the field of information technology. While the traditional waterfall model requires the completion of an entire process before implementation, the incremental approach enables the gradual construction of functional components (or versions). Within this, the educational process resembles versioned software development, where each subsequent iteration (year of study) builds upon the learning outcomes of the previous one and enhances them. This structure allows for timely updates without the need to restart the entire training system, which is particularly valuable in the context of rapidly evolving digital technologies and shifting learner needs. It ensures the continued relevance of learning content, reducing both time and resource demands associated with curriculum revisions. Such adaptability makes it possible to respond flexibly to educational demands, implement timely changes, and maintain the currency of language training, thereby supporting the step-by-step development of professional language competences and the integration of linguistic, pedagogical, and digital strategies. Such flexibility also supports the personalization of the learning process in accordance with the individual progress and professional development of engineering students [10, 15].

The model was tested among undergraduate students majoring in "Construction and Civil Engineering." The pedagogical experiment involved students from all four years of study at five leading Ukrainian universities:

- Vinnytsia National Technical University (Vinnytsia);
- National Technical University "Dnipro Polytechnic" (Dnipro);
- State University "Kyiv Aviation Institute" (Kyiv);
- State Biotechnological University (Kharkiv);
- National University "Chernihiv Polytechnic" (Chernihiv).

The course "Professional Foreign Language" was selected as an integrative component of the training programme. Its inclusion in the curriculum is aimed at equipping students with the ability to communicate in a foreign language in professional environments, including participation in real-life professional scenarios, project-related documentation, interdisciplinary teamwork, and intercultural interaction [14].

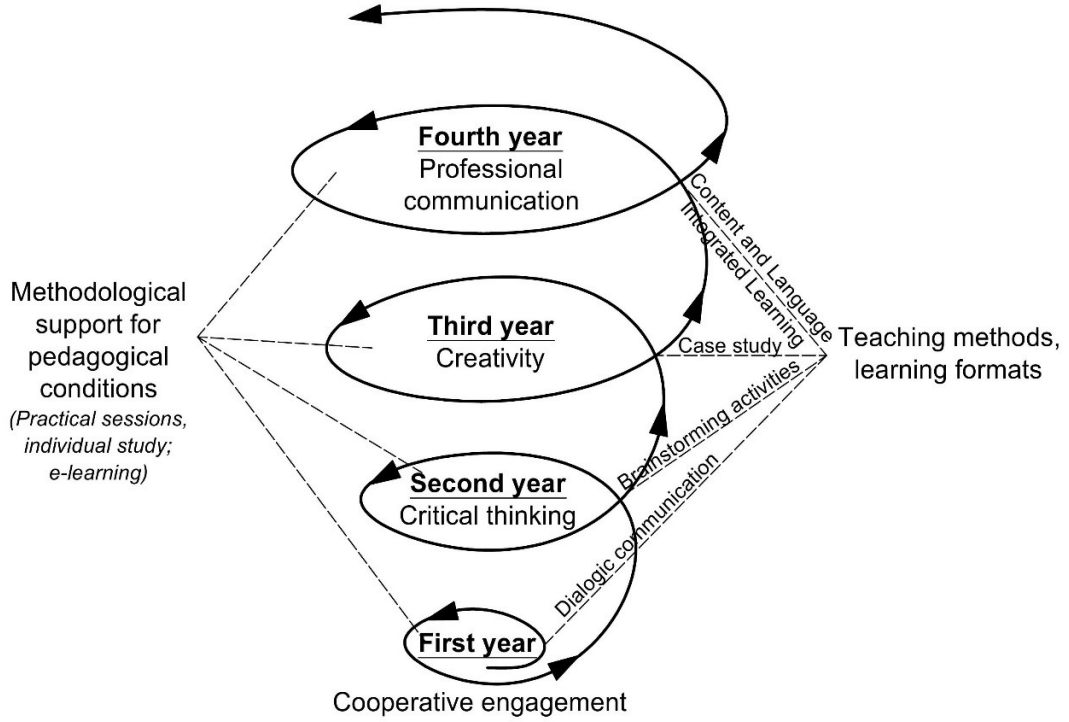

Figure 1: An incremental model of professional language training in the information and educational environment of a technical university.

Due to the uneven distribution of language courses across the four years of study in the participating universities, students who had chosen elective language modules were also involved in the model's implementation. This enabled a comprehensive assessment of the effectiveness of the model over time (Figure 1).

The proposed model outlines four incremental stages, each corresponding to a specific year of undergraduate study in a technical university. Structured as a spiral, the model reflects the progressive development and increasing complexity of professional language training. Each turn of the spiral represents one academic year during which a qualitative shift takes place, marking a transition to a higher level of language proficiency that integrates both linguistic and professional competences. Methodological support underpins every level of the model, ensuring consistent access to didactic and material resources.

The learning outcomes of each stage are recorded through structured reflection, assessment, and achievement analysis, ensuring the model remains both flexible and responsive. Adapted to the digital learning environment, the model is designed to foster students' readiness for professional communication in engineering contexts. The applied teaching methods and formats serve to operationalise the pedagogical conditions necessary for achieving the model's objectives.

These methods include dialogic communication, project-based learning, communication modelling, case analysis, brainstorming techniques, and content and language integrated learning (CLIL). The strategic integration of these techniques ensures the coherence and continuity of the incremental model, with each stage spanning one academic year and contributing to measurable progress in students' foreign language competence.

These practices help cultivate an enabling educational environment that supports the gradual development of both linguistic and professional skills while integrating cognitive, communicative, and interdisciplinary dimensions of the learning process.

During the first year of study, the primary focus was placed on developing cooperation skills, which are vital for students' initial adaptation to the university learning environment. Collaborative work serves as a highly effective strategy for fostering foreign language communication within professional

contexts, particularly in engineering education. It simulates authentic workplace scenarios in which specialists collaborate in interdisciplinary teams to address complex challenges, make collective decisions, and engage in coordinated problem-solving. These simulated tasks reflect the communicative demands engineers regularly encounter in real-world settings when negotiating technical requirements, coordinating project stages, or delivering joint presentations. Such activities not only help students practise and internalise relevant linguistic structures but also cultivate essential soft skills, including leadership, responsibility sharing, and adaptability. Moreover, group-based tasks and peer-to-peer interaction encourage students to express their ideas clearly, respond to feedback constructively, and reach consensus in a target language, skills which are critical in multilingual and multicultural professional environments. In this way, cooperation becomes a pedagogically rich practice, linking language acquisition with real-world professional competencies and enhancing students' readiness for team-based communication in global engineering contexts.

The relevance of team-based communication in language training for engineers has been emphasised by researchers such as N. Kravchenko (in the context of project-based language learning) [16], T. Bakum (in professional foreign language methodology), and R. Borah (in blended learning environments). These scholars highlight the need to integrate communication-driven strategies into the language training of future engineers [8]. Positive team dynamics not only enhance the emotional climate of the classroom but also improve academic performance and student motivation. Project-based learning is now widely recognised as an effective pedagogical strategy for developing both cooperative and communicative competences in engineering education. In addition to grammar and reading basics, students engaged in targeted activities aimed at enhancing group communication skills.

The learning process was structured around various formats, including group sessions, mini projects, situational workshops, and language quests. The dominant methods included role-play simulations, dialogic approaches (such as structured dialogues and discussions), pair work, and case-based learning. These techniques were selected with reference to first-year students' needs: fostering interpersonal trust, developing interaction skills, and understanding role distribution within teams. Assessment tools included observation of pair/group work dynamics, reflective reports, satisfaction surveys, and analysis of collaborative task outcomes. This training logic ensured an adaptable, coherent, and student-centred learning experience [9].

In the second year of language training, the focus was shifted toward the development of critical thinking as a core skill for mastering a foreign language in professional contexts. Students progressed from basic grammatical structures to working with collocations, idiomatic expressions, and specialised terminology related to construction materials and engineering systems. The course content required students to compare, analyse, and evaluate information, forming well-grounded judgements, which are the key components of critical thinking.

The development of critical thinking during foreign language learning not only enhances a deeper understanding of linguistic structures but also supports the conscious analysis of professional content. This is particularly significant in engineering, where linguistic inaccuracies can lead to the misinterpretation of technical specifications or operational requirements. Students who acquire critical thinking skills are better equipped to identify inconsistencies in technical documentation, formulate well-grounded assumptions, assess the validity of proposed solutions, and make informed engineering decisions based on precise source analysis. Furthermore, this cognitive skill underpins the ability to construct and evaluate arguments, which is essential for professional discussions, negotiations, project defences, and the peer review of engineering outcomes. Engaging with language content from a critical perspective enables learners not only to reproduce knowledge but also to generate contextually appropriate and professionally relevant conclusions.

Scholars such as V. Kovalchuk, S. Maslich, and L. Movchan underscore the role of critical thinking as a fundamental 21st-century skill that supports analytical reading, coherent expression, and reflective engagement with content. In the context of foreign language training for engineers, critical thinking supports professional communication and facilitates navigation within multilingual digital environments [12].

To improve this skill, pedagogical strategies included problem-based tasks, brainstorming sessions,

technical text analysis, crossword creation, and critical comparison of technical descriptions followed by interpretation.

The training was organised through small-group work, pair discussions, individual presentations, and debates. Assessment methods involved scenario-based tests, analytical essays, self-reflection cards, team performance evaluations, and fast-paced Q&A formats. These approaches helped develop flexible cognitive skills and enabled students to apply new knowledge to professionally relevant contexts.

In the third year, the focus was on fostering creativity in language use, a vital skill for effective communication in engineering. Creativity entails innovative thinking, idea generation, and adaptability to linguistic and situational challenges within professional discourse. Students were guided in producing original texts – project descriptions, technical specifications, manuals, and presentations – drawing on professional vocabulary and an expanded lexical repertoire [3].

Creativity plays a crucial role in successful foreign language communication within engineering contexts, as it requires unconventional thinking, the generation of original ideas, and the ability to adapt to linguistic and situational challenges in professional discourse.

During the training process, students were engaged in producing their texts, such as project descriptions, technical specifications, user instructions, and presentations, while incorporating discipline-specific terminology and an expanded technical lexicon. Particular emphasis was placed on transforming conventional information into alternative formats of expression, for instance, through the visualisation of technical content, the design of infographics, and the proposal of innovative solutions to standard tasks. Students learned to convert dry, technical data into persuasive oral or written messages ranging from internal team communication to interdisciplinary cooperation or international project presentations. A significant proportion of the learning activities consisted of time-constrained creative tasks, which encouraged rapid linguistic decision-making and enhanced students' public speaking skills.

A distinctive feature of this stage was the introduction of open-ended tasks, including the development of alternative technical solutions, the composition of innovative descriptions, the use of visual materials (e.g., infographics, technical drawings, and videos), and the simulation of non-standard communication scenarios in international contexts.

The methodology incorporated storytelling, free writing, case studies, language quests, role-play, and the 'elevator pitch' technique, particularly relevant given the growing dominance of short-form expression in digital communication. In line with the declining appeal of long-form reading and writing, students practised presenting ideas clearly and concisely in 30-60 seconds, simulating spontaneous interactions with professionals, where clear, engaging self-presentation is crucial.

Organisational formats included creative groups, idea workshops, presentation marathons, interactive simulations, and one-minute pitch sessions. Assessment of creativity involved project work, design-based tasks, and individual mini-presentations in English, evaluated for originality, topic relevance, structure, and linguistic quality. Integrating creative components enhanced students' language flexibility, ability to adapt language tools to context, and confidence in intercultural communication.

In the fourth year, the focus shifted to the consolidation of professional speaking skills. By this stage, students had mastered core grammatical structures, used idiomatic language, and demonstrated competence in technical terminology, enabling confident application of English in specialised contexts. The training process was based on authentic materials, including samples of technical documentation, academic articles, and English-language resources related to engineering technologies, ensuring a strong link between language content and the professional context. Particular emphasis was placed on the analysis of manuals, technical specifications, schematics, research reports, and specialised publications reflecting current trends in the engineering field. The integration of such materials enabled the simulation of real-life professional scenarios, fostering the development of critical reading skills, technical translation, terminological accuracy, and well-structured oral and written communication. As a result, students were provided with conditions conducive to the conscious integration of linguistic knowledge into discipline-specific tasks. An especially valuable activity was the panel discussion format, encouraging students to articulate viewpoints, defend arguments, and address professional dilemmas. Access to the university's digital learning environment enabled students to engage flexibly with relevant resources, promoting self-directed learning according to individual work rhythms.

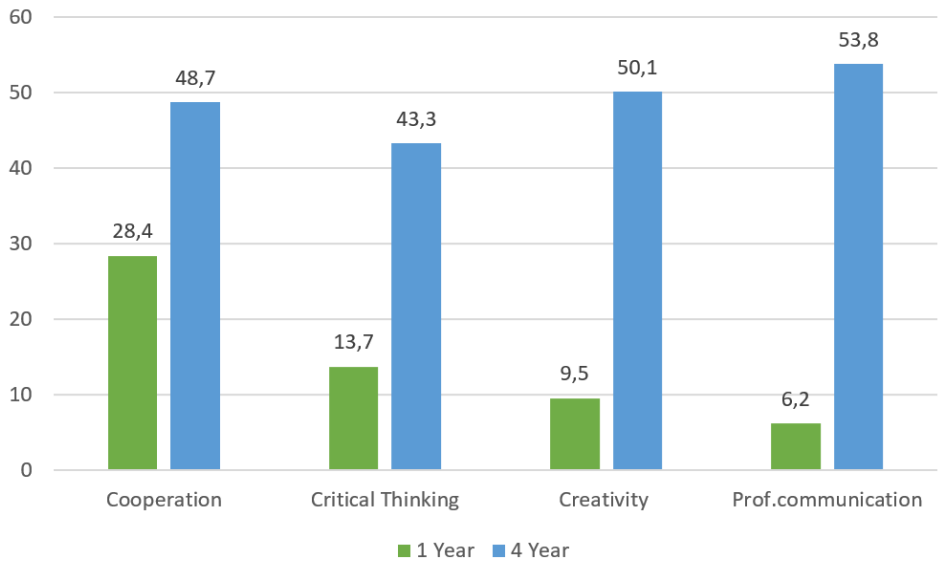

Figure 2: Skill development dynamics.

Table 1
Comparative Analysis of Skill Development Dynamics Based on the Incremental Model

Skill (4Cs)	Level in Year 1 (%)	Level in Year 4 (%)	Growth (%)
Cooperation	28.4	48.7	20.3
Critical Thinking	13.7	43.3	29.6
Creativity	9.5	50.1	40.6
Professional Communication	6.2	53.8	47.6

Pedagogical methods included simulations, scenario-based role-play, business games, peer review, and CLIL (Content and Language Integrated Learning). Organisational formats encompassed mini-conferences, panel discussions, peer-reviewed talks, and professional workshops. Assessment was conducted through practical language use tasks, portfolio evaluation, and technical blog/report submissions [4]. The emphasis on professional speaking enabled students to demonstrate linguistic proficiency and cultivate a personal communication style suited to the engineering field.

3. Interpretation of experimental findings

The data presented in Table 1 and the diagram in Figure 2 reflect moderate yet steady progress in the development of key skills in professional language training within the incremental model.

According to Figure 2, all four skills – cooperation, critical thinking, creativity, and professional communication – demonstrated a positive progression from Year 1 to Year 4. The most significant improvement was observed in professional communication (from 6.2% to 53.8%), reflecting its integration into advanced language tasks. Although the initial levels were relatively low, the results indicate the steady effectiveness of the incremental model in fostering targeted professional language skills over time.

Table 1 shows a comparative overview of skill development across four academic years, illustrating the progression achieved through the implementation of the incremental model. It highlights percentage changes in key skill areas.

Initial measurements conducted during the first year of implementation revealed a generally low level of professional skill acquisition among students. Specifically, the results indicated the following performance rates: Cooperation – 28.4%, Critical Thinking – 13.7%, Creativity – 9.5%, and Professional

Communication – 6.2%. These outcomes are characteristic of the initial (adaptive) stage of training and can be attributed to students' limited prior exposure to discipline-specific language tasks and a general lack of experience in engaging with professional communication formats in a foreign language. At this stage, learners typically require time to adjust to unfamiliar terminologies, task types, and digital communication tools embedded in the training process.

By the end of the fourth year, after completing all stages of the incremental model, a substantial increase was recorded across all assessed indicators: Cooperation – 48.7%, Critical Thinking – 43.3%, Creativity – 50.1%, and Professional Communication – 53.8%. The overall improvement ranged from +20.3% to +47.6%, indicating a gradual and systematically structured progression that avoided cognitive overload or undue instructional pressure. This steady development reflects the effectiveness of the model in maintaining optimal cognitive engagement while building students' professional language competence over time.

The most significant growth was observed in Professional Communication (+47.6%), which is consistent with the design of the final stage of the model. At this stage, learners engage with authentic disciplinary content, prepare and deliver technical presentations, and participate in simulated professional interactions. Such tasks promote situated language use and require the transfer of theoretical knowledge to communicative performance within specialised contexts.

Notable increases were also recorded in Creativity (+40.6%) and Critical Thinking (+29.6%). These gains are closely linked to the deliberate integration of project-based tasks, problem-solving scenarios, and analytical assignments throughout the training sequence. The consistent use of such methods encouraged students to generate original ideas, evaluate information critically, and engage in reflective language production.

By contrast, the skill of Cooperation demonstrated the least dynamic growth (+20.3%), which may point to a relative underemphasis on collaborative learning activities in the later stages of the programme. This outcome suggests the need for a more sustained focus on group interaction formats, particularly when individualised or research-focused assignments become more prevalent in senior years.

Overall, the data indicate that the incremental model supports a stable and logically sequenced trajectory of professional language development in engineering students. Although growth patterns were moderate in absolute terms, their consistency and correlation with specific pedagogical interventions validate the effectiveness of the model. The results confirm that gradual, cumulative progression, anchored in authentic tasks and methodologically diverse instruction, can yield meaningful advances in profession-oriented communicative competence within a digitally enhanced academic environment.

4. Conclusions

Thus, the proposed incremental model of professional language training has demonstrated its effectiveness in providing a staged, systematically organised development of key cognitive, communicative, and social skills essential for the professional development of future engineering specialists. By integrating cooperation, critical thinking, creativity, and professional communication within successive incremental stages, the model established a coherent pedagogical system that supports the sustained advancement of language proficiency within the context of specialised engineering education. Simultaneously, the model enhances learners' readiness to engage in professional linguistic practices in settings marked by interdisciplinary communication and the digital transformation of educational environments. It also corresponds with the broader transformation of language education in the digital era, which calls for a rethinking of pedagogical approaches, tools, and formats.

A distinctive feature of the model lies in its adaptability to the dynamic conditions of digital learning environments, addressing contemporary challenges while promoting autonomy in learning, critical evaluation of information, and effective intercultural communication. The implementation relied on evidence-based pedagogical strategies, including project-based learning, dialogic methods, problem-solving tasks, brainstorming, work with technical texts, language quests, and project defence formats. These strategies supported student engagement and ensured the integration of language content with

domain-specific communication. The systematic implementation of incremental stages contributed not only to improved foreign language competence but also to the development of educational and professional mobility, reflective practice, and strategic planning of career development. In this context, the incremental model proves to be an effective tool for integrating linguistic and profession-oriented components in the training of competitive technical specialists.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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