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A Deep-CLIL Approach to Developing English for Mining Materials in Higher Education

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Abstract. The increasing demand for English communication in the global mining industry requires higher education institutions to provide instructional materials that integrate disciplinary knowledge, language development, and professional competencies. However, English courses in mining-related programs remain largely generic and insufficiently aligned with students' academic and workplace needs. This study aimed to develop and validate deep content and language integrated learning (deep-CLIL)-based English for mining materials for higher education. Employing a design and development research (DDR) approach, the study involved 106 undergraduate students from five Indonesian universities, 15 interview participants, and three expert validators. Data were collected through questionnaires, semi-structured interviews, and expert validation checklists and were analyzed using descriptive statistics and thematic analysis. The needs analysis identified strong demand for contextualized mining content, particularly mining operations, geological exploration, environmental management, and occupational safety. Speaking emerged as the highest-priority language skill. Students strongly supported project-based learning, authentic workplace tasks, collaborative learning, and critical-thinking activities. These findings informed the development of the deep-CLIL framework, which extends the conventional CLIL 4Cs (content, communication, cognition, and culture) by explicitly integrating deep learning principles to promote meaningful knowledge construction and workplace readiness. The resulting materials comprised 10 thematic units incorporating authentic mining scenarios, collaborative projects, reflective learning, and performance-based assessment. Expert validation demonstrated very high validity across all dimensions (overall M = 4.80), confirming the quality and feasibility of the developed materials. The study contributes a theoretically grounded and empirically validated framework that offers

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practical guidance for developing discipline-specific English materials in higher education.

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1. Introduction

The increasing internationalization of the mining industry has transformed English into an essential medium for professional communication, technological exchange, scientific dissemination, and cross-border collaboration (Xu & Chen, 2026). As noted by Costa et al. (2022), contemporary professionals are expected to access disciplinary knowledge, communicate technical information, and participate in global professional communities through English. In mining-related sectors, English proficiency is increasingly required for interpreting technical reports, understanding international safety regulations, engaging in multinational projects, and accessing rapidly evolving technological innovations.

While these communicative demands have traditionally been addressed through English for specific purposes (ESP), which emphasizes profession-specific language and workplace communication, they also require learners to develop a robust understanding of disciplinary concepts and the ability to apply such knowledge in authentic professional contexts. Therefore, rather than focusing solely on occupation-specific language, this study adopts a deep-CLIL approach that integrates disciplinary knowledge, language development, critical thinking, and authentic learning tasks, enabling students to construct both conceptual understanding and professional communicative competence simultaneously. Consequently, higher education institutions are under growing pressure to prepare graduates who possess not only disciplinary expertise but also the linguistic competencies necessary to function effectively in global professional environments (Costa et al., 2022; Tai et al., 2025).

Despite these demands, English instruction in many mining-related higher education programs remains largely disconnected from disciplinary learning and workplace communication needs. ESP scholars have long argued that language instruction should be designed based on learners' academic and professional requirements rather than generalized language objectives (Dudley-Evans & John, 1998; Hutchinson & Waters, 1987). Nevertheless, many English courses continue to emphasize grammar-focused instruction and general communicative competence while providing limited opportunities for students to engage with authentic disciplinary content. As a result, students frequently experience difficulties transferring classroom-acquired language skills into professional contexts that require technical communication, problem-solving, and critical engagement with discipline-specific issues (Canz et al., 2021; Costa et al., 2022).

Content and language integrated learning (CLIL) has emerged as a prominent pedagogical approach for integrating language learning with disciplinary knowledge through meaningful engagement with subject matter, positioning

language as a vehicle for knowledge construction rather than an isolated learning objective (Kaiypova et al., 2025). Numerous studies have demonstrated that CLIL enhances language development, content acquisition, learner motivation, and communicative competence across diverse educational settings, while supporting academic achievement in increasingly multilingual contexts (Canz et al., 2021; Smit & Finker, 2022; Sula & Hoxha, 2026; Tai et al., 2025). Central to its pedagogical value is the 4Cs framework of content, communication, cognition, and culture which promotes the simultaneous development of disciplinary knowledge, language competence, higher-order thinking, and intercultural awareness (Dalton-Puffer, 2007; Kaiypova et al., 2025). Recent scholarship further argues that effective CLIL should move beyond language-content integration by engaging learners in disciplinary inquiry, problem-solving, and multilingual meaning-making through authentic communicative practices (Kos & Bergner, 2025; Tai et al., 2025).

Parallel developments in higher education have emphasized deep learning as an approach that fosters conceptual understanding, critical thinking, knowledge integration, reflection, and the transfer of learning to authentic contexts rather than memorization (Hu et al., 2025; Zhang et al., 2025). Likewise, recent CLIL research highlights the importance of authentic disciplinary tasks that integrate language learning with disciplinary literacy and cognitive engagement (Xia & Li, 2026). Together, these complementary perspectives suggest that meaningful learning occurs when students actively construct knowledge through authentic, contextually relevant experiences that integrate cognitive, social, and disciplinary dimensions (Tai et al., 2025). Building on this convergence, the present study proposes deep-CLIL, which extends conventional CLIL by explicitly integrating deep learning principles to promote critical inquiry, knowledge transfer, authentic communication, and professional competence in English for mining (Alamoudi & Butt, 2026; Hu et al., 2025; Xia & Li, 2026).

Although research on CLIL has expanded considerably over the last decade, it has primarily focused on language outcomes, learner motivation, assessment, multilingual interaction, and technology-enhanced learning rather than the development of discipline-specific instructional materials (Canz et al., 2021; Hu et al., 2025; Smit & Finker, 2022; Tai et al., 2025; Xia & Li, 2026). Similarly, deep learning research has predominantly examined cognitive engagement, student achievement, learning analytics, and technology-enhanced learning in general educational contexts (Alamoudi & Butt, 2026).

Consequently, limited attention has been devoted to integrating deep learning principles into CLIL-based ESP materials that simultaneously promote disciplinary knowledge, language development, higher-order thinking, and authentic professional engagement. This gap is particularly evident in mining education, in which domain contextualized English learning resources remain scarce despite the growing demand for English communication in the global mining industry. To address this gap, the present study proposed deep-CLIL for developing English for mining materials in higher education. Extending the conventional CLIL 4Cs framework, deep-CLIL explicitly integrates deep learning

principles including critical inquiry, knowledge integration, reflective learning, authentic problem-solving, and contextualized professional engagement within a unified pedagogical model.

Grounded in a comprehensive needs analysis involving mining students from multiple universities, this study addresses four research questions: (1) What English language learning needs do mining engineering students perceive for effective English for mining instruction? (2) How can deep-CLIL be conceptualized to address these identified needs? (3) How does the deep-CLIL framework contribute to the development of contextualized English for mining materials? and (4) How valid and appropriate are the proposed deep-CLIL framework and its accompanying instructional materials for English for mining in higher education? The study contributes theoretically by extending CLIL scholarships through the integration of deep learning principles into ESP materials development and practically by providing a validated, contextualized instructional model to support the preparation of globally competent mining graduates.

2. Literature Review

2.1 Content and Language Integrated Learning in Higher Education

One of the most influential approaches for integrating language learning with disciplinary knowledge in multilingual education is CLIL. Defined as a dual-focused approach in which the target language serves as the medium for learning both content and language (Aizawa & Suzukida, 2026), CLIL positions language as a tool for constructing disciplinary understanding through authentic academic and professional contexts rather than as an isolated learning objective (Coyle et al., 2010). Its theoretical foundation, the 4Cs framework, promotes the integrated development of disciplinary knowledge, language competence, higher-order thinking, and intercultural awareness (Aizawa & Suzukida, 2026; Coyle et al., 2010; Ma et al., 2025).

A growing body of evidence indicates that CLIL enhances language proficiency, content learning, learner engagement, disciplinary literacy, and collaborative problem-solving by immersing learners in meaningful disciplinary communication (Alamoudi & Butt, 2026; Macaraeg et al., 2024; Smit & Finker, 2022; Kos & Bergner, 2026; Tai et al., 2025). Nevertheless, recent studies consistently report that the cognition dimension remains the least developed in practice, as instruction often prioritizes content coverage and language acquisition over critical inquiry, reflection, and authentic problem-solving, particularly in specialized ESP contexts (Alamoudi & Butt, 2026; Hu et al., 2025; Kos & Bergner, 2026; Xia & Li, 2026).

Responding to this limitation, the present study proposed the deep-CLIL framework, which extends the conventional CLIL 4Cs by explicitly integrating deep learning principles to strengthen cognitive engagement through critical inquiry, knowledge integration, reflective learning, authentic problem-solving, and contextualized professional communication, thereby promoting disciplinary

understanding and workplace readiness in English for mining education (Tai et al., 2025; Xin et al., 2025).

2.2 Deep Learning in Higher Education

Deep learning is increasingly conceptualized as a learner-centered approach in which students construct meaningful understanding by integrating new knowledge with prior experiences, engaging in critical inquiry, and applying knowledge to authentic contexts rather than relying on memorization or surface-level learning (Zhang et al., 2025). This perspective builds on the seminal distinction between deep and surface approaches to learning introduced by Xia and Li (2026), in which deep learning is characterized by conceptual understanding, knowledge integration, reflection, and the transfer of learning across contexts, whereas surface learning emphasizes the reproduction of isolated facts.

Consequently, deep learning promotes higher-order cognitive processes, including analysis, evaluation, problem-solving, and knowledge application, which are essential for developing meaningful and sustainable learning outcomes (Levin, 2024; Zhang et al., 2025). Recent studies consistently demonstrate that deep learning enhances learner engagement, conceptual understanding, critical thinking, and long-term academic achievement, making it an important pedagogical approach for preparing students to address complex disciplinary and professional challenges (Levin, 2024; Zhang et al., 2025).

Recent empirical evidence further supports the educational value of deep learning. Hidalgo and Villarreal (2024) reported that learning environments emphasizing meaningful engagement, reflection, and personalized learning pathways significantly improved students' academic performance and learning satisfaction. Zhang et al. (2025) found that authentic learning experiences foster conceptual understanding, critical inquiry, and knowledge integration. These findings suggest that deep learning extends beyond cognitive achievement by enabling learners to apply disciplinary knowledge in authentic contexts.

Such capabilities are particularly important in professional disciplines, such as mining engineering, in which graduates must analyze complex information, evaluate environmental and social impacts, solve workplace problems, and make evidence-based decisions (Biggs & Tang, 2011; Costa et al., 2022). Accordingly, deep learning provides the cognitive foundation for the proposed deep-CLIL framework by strengthening the cognition dimension of CLIL through critical inquiry, reflective learning, authentic problem-solving, and knowledge transfer in discipline-specific contexts.

2.3 Integrating ESP and CLIL for English for Mining Materials Development

English for specific purposes (ESP) is widely recognized as a needs-based approach that aligns language instruction with learners' academic and professional requirements through systematic needs analysis, which informs curriculum design, instructional strategies, assessment, and materials development (Hutchinson & Waters, 1987; Dudley-Evans & John, 1998). Recent

studies have shown that contextualized ESP instruction enhances disciplinary communication, professional confidence, and the application of English in authentic workplace settings, particularly when learning is supported by authentic disciplinary tasks and materials (Tomlinson, 2013, 2016; Xia & Li, 2026).

Although ESP and CLIL share the goal of contextualized language learning, they play complementary roles: ESP identifies the disciplinary content, communicative practices, and workplace competencies required by learners, whereas CLIL provides the pedagogical framework for integrating language and content through meaningful learning experiences (Hu et al., 2025; Xia & Li, 2026). A recent systematic review further concluded that CLIL enhances both language proficiency and content learning, especially when implemented through student-centered and technology-enhanced pedagogies, while highlighting the need for approaches that promote deeper cognitive engagement (Hu et al., 2025).

Building on these complementary perspectives, the present study positioned ESP as the foundation for identifying mining-related learning needs and CLIL as the instructional framework for integrating language, disciplinary knowledge, and cognition. These perspectives are further extended through the proposed deep-CLIL framework, which explicitly incorporates deep learning principles to promote critical inquiry, knowledge integration, reflective learning, and authentic professional engagement in English for mining education.

2.4 Conceptualizing Deep-CLIL for English for Mining Materials

The reviewed literature demonstrates that CLIL and deep learning are conceptually complementary yet have largely evolved as separate research traditions. CLIL emphasizes the integration of content and language learning (Aizawa & Suzukida, 2026); deep learning promotes meaningful knowledge construction and higher-order thinking (Biggs & Tang, 2011); and ESP advocates contextualized instruction based on learners' academic and professional needs (Hutchinson & Waters, 1987). However, CLIL research has predominantly focused on language outcomes, learner motivation, assessment, and multilingual interaction (Alamoudi & Butt, 2026; Beaudin, 2022; Canz et al., 2021; Smit & Finker, 2022). In contrast, deep learning studies have mainly examined cognitive engagement, academic achievement, and technology-enhanced learning (Hidalgo & Villarreal, 2024), leaving the integration of deep learning principles into CLIL-based ESP materials largely underexplored, particularly in mining education.

Addressing this gap, the present study proposed the deep-CLIL framework, which extends the CLIL 4Cs framework by integrating authentic disciplinary knowledge, professional communication, critical inquiry, reflective learning, authentic problem-solving, and contextualized professional engagement. Specifically, content emphasizes knowledge construction through authentic mining issues; communication promotes workplace interaction; cognition incorporates deep learning processes; and culture is reconceptualized to encompass the social, environmental, ethical, and global dimensions of mining practice. Grounded in both theoretical perspectives and empirical needs-analysis findings, deep-CLIL provides a coherent conceptual foundation for developing

contextualized English for mining materials that simultaneously fosters language proficiency, disciplinary understanding, higher-order thinking, and workplace readiness in higher education.

3. Methodology

3.1 Research Design

This study employed design and development research (DDR) to develop and validate deep-CLIL-based English for mining materials for higher education. DDR was selected because the study sought not only to investigate learners' needs but also to systematically design, develop, validate, and refine an instructional product grounded in both theory and empirical evidence. According to Richey and Klein (2007), DDR provides a systematic framework for developing and evaluating educational products while simultaneously generating practical and theoretical knowledge.

This approach aligns with the present study, which integrates the complementary strengths of ESP, CLIL, and deep learning into a unified instructional framework. Specifically, ESP informed the identification of discipline-specific content and workplace communication needs; CLIL provided the pedagogical basis for integrating language and content; and deep learning contributed to critical inquiry, authentic problem-solving, reflective learning, and collaborative knowledge construction to foster disciplinary understanding, higher-order thinking, and professional competence.

The study adopted Type 1 DDR (Richey & Klein, 2007), which focuses on the development and evaluation of educational products. This model was appropriate because the objective was to produce a validated set of English for mining materials rather than to evaluate instructional effectiveness through large-scale implementation. The development process comprised four interconnected phases: (1) needs analysis, (2) conceptualization of the deep-CLIL framework, (3) instructional materials development, and (4) expert validation and revision. This systematic process addressed the lack of contextualized English for mining materials that integrates disciplinary knowledge, language learning, higher-order thinking, and authentic workplace practices, resulting in a theoretically grounded and pedagogically validated instructional model for higher education.

3.2 Research Context

The study was conducted in five Indonesian higher education institutions offering mining-related programs. These institutions were selected because they provide English courses as part of their curriculum but have not yet implemented English for mining materials specifically designed to integrate disciplinary content with language learning. Consequently, they provided an appropriate context for investigating students' academic and professional English learning needs and for developing the proposed deep-CLIL instructional materials.

3.3 Participants

The needs analysis involved 106 undergraduate students enrolled in mining-related programs at five Indonesian higher education institutions. Participants were selected using criterion-based purposive sampling because they met predefined inclusion criteria and represented the target users of the proposed English for mining materials (Patton, 2015; Creswell & Creswell, 2018). Eligible participants were enrolled in a mining-related program, had completed at least one university-level English course, were actively engaged in mining-related academic activities, and provided informed consent. The majority were second-year and third-year students, who had already experienced university-level English instruction and, therefore, were well positioned to evaluate the strengths and limitations of existing English learning materials and articulate their expectations for English for mining instruction.

Subsequently, 15 students were selected through maximum variation purposive sampling to capture diverse perspectives across universities, academic years, and English learning experiences, thereby enriching the qualitative findings and strengthening the triangulation of the quantitative results (Patton, 2015; Creswell & Poth, 2018).

Table 1: Demographic characteristics of participants (N = 106)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	68	64.2
	Female	38	35.8
Age	18–19 years	29	27.4
	20–21 years	51	48.1
	22–23 years	20	18.9
	>23 years	6	5.6
Academic Year	First Year	21	19.8
	Second Year	37	34.9
	Third Year	29	27.4
	Fourth Year	19	17.9
English Course Experience	One Course	32	30.2
	Two Courses	45	42.5
	Three or More Courses	29	27.3

The demographic profile suggests that the majority of participants were second-year and third-year students who had already experienced university-level English instruction. Consequently, they were considered capable of providing informed perspectives regarding the strengths and limitations of existing English learning materials and their expectations for future English for mining instruction.

3.4 Research Instruments

To collect quantitative and qualitative data, three instruments were utilized.

3.4.1 Needs analysis questionnaire

The primary instrument was a researcher-developed questionnaire based on ESP needs analysis literature (Dudley-Evans & John, 1998), the CLIL 4Cs framework

(Coyle et al., 2010), and deep learning principles (Biggs & Tang, 2011). The questionnaire consisted of six dimensions as listed in Table 2.

Table 2: Questionnaire blueprint

Dimension	Indicators	Example Item
Content Needs	Mining topics and disciplinary knowledge	"I need English materials related to mining safety procedures."
Language Needs	Listening, speaking, reading, writing	"Speaking skills are important for my future career in mining."
Cognition	Critical thinking and problem-solving	"English learning should include analysis of mining-related issues."
Culture/Context	Industry and workplace context	"Learning materials should reflect real mining industry situations."
Integration	Content-language integration	"English learning should integrate language and mining content."
Learning Preferences	Instructional activities	"I prefer project-based learning activities."

The questionnaire contained 42 Likert-scale items and five open-ended questions. The questionnaire items were adapted from three theoretical sources: ESP needs analysis, the CLIL 4Cs framework, and deep learning principles. The adaptation process began by identifying the main constructs relevant to the study, namely content needs, language needs, cognition, culture/context, content-language integration, and learning preferences. These constructs were then translated into context-specific indicators for mining education, such as technical topics, workplace communication, critical-thinking tasks, authentic mining situations, and preferred learning activities.

Existing concepts were not copied directly; instead, they were reworded and contextualized to reflect the academic and professional needs of mining students. The initial item pool was reviewed by experts in ESP, CLIL, and mining education, revised for clarity and relevance, and then piloted with students who had characteristics similar to the target participants. The final instrument consisted of 42 Likert-scale items and five open-ended questions.

3.4.2 Expert validation checklist

An expert validation checklist was developed to evaluate the quality and appropriateness of the proposed deep-CLIL framework and its accompanying English for mining materials. The checklist was adapted from established principles of instructional materials evaluation (Tomlinson, 2013, 2016), the CLIL 4Cs framework (Coyle et al., 2010), ESP materials development (Dudley-Evans & John, 1998), and deep learning principles (Biggs & Tang, 2011), with these theoretical constructs translated into evaluation indicators relevant to English for mining. Prior to implementation, the checklist was reviewed by experts in ESP, CLIL, and mining education to ensure its clarity, relevance, and content validity. The finalized instrument comprised 25 items across the five dimensions of content quality, language quality, deep-CLIL alignment, learning design, and practicality (five items each) (Table 3). Each item was rated on a five-point Likert scale ranging

from 1 (very poor) to 5 (excellent), with higher scores indicating greater quality, relevance, and implementation feasibility of the proposed framework and instructional materials.

Table 3: Expert validation dimensions

Dimension	Indicators
Content Quality	Accuracy, relevance, completeness
Language Quality	Clarity, appropriateness, readability
Deep-CLIL Alignment	Integration of content, communication, cognition, culture
Learning Design	Learning activities, assessment, sequencing
Practicality	Usability and implementation feasibility

3.4.3 Semi-structured interview protocol

To complement the questionnaire data and obtain a deeper understanding of the findings, the interview protocol consisted of nine semi-structured interview items, each representing one key dimension of the study. The protocol was developed based on three theoretical foundations of ESP needs analysis, the CLIL 4Cs framework, and deep learning principles. The nine interview items explored students' experiences with existing English instruction, perceived learning difficulties, English language needs for mining contexts, language skill priorities, higher-order learning expectations, authentic workplace communication needs, preferred learning activities, perceptions of integrating mining content with language learning, and recommendations for the development of deep-CLIL instructional materials. Each item served as a broad guiding question, allowing the interviewer to use follow-up probes to obtain richer and more detailed responses, while maintaining the flexibility characteristic of semi-structured interviews (Creswell & Creswell, 2018).

A total of 15 students were purposively selected for interviews based on their willingness to participate and their ability to provide detailed information regarding English learning experiences. The interview participants represented different academic years and institutions to ensure diversity of perspectives. Each interview lasted approximately 20–30 minutes and was conducted either face-to-face or through online video conferencing platforms. All interviews were audio-recorded with participants' consent and subsequently transcribed for analysis.

Table 4: Semi-structured interview matrix

Dimension	Objective	Sample Questions
Existing English Learning Experience	To explore students' perceptions of current English instruction	How would you describe your experience learning English at university? What aspects of the current English courses are most useful?
Learning Difficulties	To identify challenges encountered when learning English	What difficulties do you face when learning English? Which language skills are the most challenging for you? Why?
English for Mining Needs	To identify specific linguistic needs related to mining studies	What types of English do you need most for your mining studies? What mining-related topics should be included in English materials?
Language Skills Priorities	To determine priority language skills for academic and professional purposes	Which English skills (listening, speaking, reading, writing) are most important for your future career in mining? Please explain.
Cognition and Critical Thinking	To explore students' expectations regarding higher-order learning activities	Do you think English learning should involve problem-solving, case analysis, or critical discussions related to mining issues? Why?
Authentic Mining Contexts	To identify workplace communication needs and authentic contexts	Have you ever encountered English during internships, fieldwork, technical reading, or mining-related activities? What kinds of communication situations were involved?
Learning Activities and Preferences	To identify preferred instructional strategies	What kinds of learning activities help you learn English more effectively? Do you prefer projects, discussions, case studies, presentations, simulations, or other activities?
Integration of Content and Language	To explore perceptions regarding CLIL-oriented learning	How important is it to integrate mining content and English learning in the same lesson? What benefits do you expect from such integration?
Expectations for Deep-CLIL Materials	To gather recommendations for the developed materials	If a new English for mining textbook were developed, what features, topics, and learning activities would you like to see included?

The interview findings were used to complement the quantitative needs analysis results and provide richer insights into students' academic, linguistic, cognitive, and professional needs. The qualitative data also informed the formulation of design principles underlying the deep-CLIL framework and the development of the instructional materials.

3.4.4 Trustworthiness of interview data

The trustworthiness of the qualitative findings was established following the criteria of credibility, dependability, transferability, and confirmability (Lincoln & Guba, 1985; Creswell & Poth, 2018). Credibility was enhanced through member checking, whereby interview summaries were returned to selected participants

for verification to ensure that the researchers' interpretations accurately reflected their perspectives. In addition, peer debriefing was conducted throughout the coding and interpretation process to discuss emerging themes, challenge interpretations, and minimize researcher bias. Dependability was supported by maintaining an audit trail documenting the procedures for data collection, coding, theme development, and analysis.

Transferability was strengthened by providing detailed descriptions of the research context, participants, and data collection procedures, enabling readers to judge the applicability of the findings to similar educational settings. Confirmability was ensured through the preservation of interview transcripts, coding records, and analytic memos, allowing the findings to be traced directly to the participants' accounts rather than the researchers' assumptions (Lincoln & Guba, 1985; Tracy, 2020). Collectively, these procedures enhanced the rigor, transparency, and trustworthiness of the qualitative findings.

3.5 Data Collection Procedures

Data were collected over a four-month period (January–April 2026) following the DDR framework (Richey & Klein, 2007), in which empirical evidence informed the design, development, and validation of the deep-CLIL-based English for mining materials. The process began with a needs analysis involving 106 undergraduate mining students from five Indonesian universities. After institutional approval and informed consent were obtained, participants completed an online questionnaire comprising closed-ended and open-ended items exploring existing English instruction, content and language needs, learning challenges, cognitive expectations, and preferences for integrating mining content with language learning.

To complement this data, semi-structured interviews were conducted with 15 purposively selected students representing different universities and academic years. Lasting 20–30 minutes, the interviews explored experiences with existing materials, perceived learning challenges, and expectations for contextualized English for mining instruction. Interview data were used to triangulate and explain the quantitative findings, strengthening the credibility of the needs analysis.

The integrated findings were subsequently translated into the design specifications of the deep-CLIL framework, informing instructional objectives, content selection, learning activities, assessment tasks, and authentic mining contexts. Based on these specifications, an initial prototype comprising 10 thematic units was developed and evaluated by three experts in ESP, CLIL, and mining education using a structured validation checklist. Their quantitative ratings and qualitative feedback informed iterative revisions to content organization, language clarity, instructional design, and the integration of deep-CLIL principles, resulting in the final version of the instructional materials.

3.6 Data Analysis

3.6.1 Quantitative data analysis

Quantitative data obtained from the needs analysis questionnaire and expert validation checklist were analyzed using descriptive statistical procedures in IBM SPSS Statistics Version 29. The analysis aimed to identify students' priority needs and evaluate the quality of the developed materials. Percentages, means, and standard deviations were calculated to describe response patterns across all questionnaire dimensions. To facilitate interpretation, each dimension was analyzed according to specific indicators and analytical purposes.

Table 5: Quantitative data analysis matrix

Data Source	Dimension	Statistical Analysis	Summary of Findings	Purpose
Needs Analysis Questionnaire	Content Needs	Frequency, Percentage, Mean, SD	Strong preference for contextualized mining topics (M = 4.39, SD = 0.61)	Identify content priorities
	Language Needs	Frequency, Percentage, Mean, SD	Speaking identified as the highest-priority language skill (M = 4.31, SD = 0.68)	Determine language skill priorities
	Cognition	Frequency, Percentage, Mean, SD	High expectation for critical thinking and problem-solving (M = 4.26, SD = 0.70)	Identify cognitive expectations
	Culture/ Context	Frequency, Percentage, Mean, SD	Need for authentic workplace contexts and professional relevance (M = 4.18, SD = 0.74)	Determine contextual learning needs
	Integration Needs	Frequency, Percentage, Mean, SD	Strong support for content-language integration and project-based learning (M = 4.71, SD = 0.49)	Examine support for deep-CLIL
	Learning Preferences	Frequency, Percentage, Mean, SD	Preference for authentic, collaborative, and inquiry-based learning (M = 4.47, SD = 0.58)	Inform instructional design
Expert Validation Checklist	Content Quality	Mean, SD	M = 4.82	Evaluate content validity
	Language Quality	Mean, SD	M = 4.76	Evaluating language quality
	Deep-CLIL Alignment	Mean, SD	M = 4.91	Evaluate framework implementation
	Instructional Design	Mean, SD	M = 4.79	Evaluate pedagogical quality
	Practicality	Mean, SD	M = 4.73	Evaluating implementation readiness

Descriptive statistical analysis identified several important patterns regarding students' English for mining learning needs. Frequency and percentage analyses revealed that the most preferred content areas were mining industry overview (80.2%), mining methods (74.5%), geological exploration (70.8%), environmental impacts of mining (68.9%), and occupational safety and personal protective equipment (65.1%), indicating a strong preference for workplace-oriented disciplinary content. Regarding language skills, speaking in technical discussions emerged as the highest priority (65.1%), followed by reading technical documents (39.6%), listening to instructions and training (34.9%), and writing reports and correspondence (27.4%).

The cognitive dimension showed that 81.0% of participants expected English learning to promote critical thinking, while 56.7% reported confidence in analyzing mining concepts using English. Concerning contextual needs, 63.8% of students indicated that they had encountered English during internships, field projects, seminars, or industrial visits, although only 20.0% perceived the existing English materials as highly relevant to workplace requirements. The integration dimension demonstrated exceptionally strong support for the proposed instructional model, with 97.1% of participants expressing interest in integrating English learning with mining content and 93.3% supporting project-based learning approaches.

These descriptive findings served as the empirical basis for developing the deep-CLIL framework and the English for mining instructional materials. Expert validation further confirmed the quality of the developed materials, yielding very high mean scores for content quality ($m = 4.82$), language quality ($m = 4.76$), deep-CLIL alignment ($m = 4.91$), instructional design ($m = 4.79$), and practicality ($M = 4.73$), with an overall mean score of 4.80, indicating that the materials were highly valid and appropriate for implementation.

3.6.2 *Qualitative data analysis*

Qualitative data derived from open-ended questionnaire responses, semi-structured interviews, and expert feedback were analyzed using thematic analysis following Braun and Clarke's (2006) six-phase framework. The analysis began with repeated reading of the transcripts and written responses to achieve data familiarization. Subsequently, meaningful units of information were coded and grouped into preliminary categories. Similar categories were then clustered into broader themes representing students' academic, linguistic, cognitive, and professional learning needs. The themes were continuously reviewed and refined to ensure coherence, consistency, and alignment with the study objectives. To enhance credibility, two researchers independently reviewed the coding process and discussed discrepancies until consensus was achieved. Member checking was also conducted with selected interview participants to confirm the accuracy of interpretations.



Credibility Procedures: Independent Coding by Two Researchers • Consensus Discussions • Member Checking

Figure 1: Qualitative data analysis procedure

3.6.3 Integration and triangulation of findings

Following separate quantitative and qualitative analyses, the findings were integrated through methodological triangulation to enhance the credibility and comprehensiveness of the needs analysis. Qualitative interview data were used to explain and contextualize quantitative patterns by clarifying students' priorities and the underlying reasons for their responses. This integration enabled statistical trends to be interpreted within authentic educational and professional mining contexts rather than through numerical indicators alone. The synthesized findings subsequently informed the design of the deep-CLIL framework, guiding the selection of disciplinary content, language objectives, higher-order cognitive tasks, learning activities, assessment strategies, and authentic mining contexts for the development of the instructional materials.

3.6.4 Instrument validity and reliability

The needs analysis questionnaire, semi-structured interview protocol, and expert validation checklist underwent systematic content validation before data collection to ensure their suitability for developing deep-CLIL-based English for mining materials. The instruments were constructed based on the theoretical foundations of ESP needs analysis (Dudley-Evans & John, 1998), the CLIL 4Cs framework (Coyle et al., 2010), and deep learning principles (Biggs & Tang, 2011). Three experts evaluated the relevance, clarity, representativeness, and comprehensiveness of each item using a four-point relevance scale, and the content validity index (CVI) was calculated to determine content validity. The results demonstrated strong validity, with item-level CVI (I-CVI) values ranging from .83 to 1.00 and a scale-level CVI (S-CVI/Ave) of .94 for the questionnaire, .96

for the interview protocol, and .97 for the expert validation checklist, all exceeding recommended validity thresholds. Based on the experts' feedback, minor revisions were made to improve wording clarity, contextual relevance, and alignment with the deep-CLIL constructs before the instruments were administered.

Table 5: Content validity results

Instrument	Number of Items	S-CVI/Ave	Interpretation
Needs Analysis Questionnaire	42	.94	Excellent
Semi-Structured Interview Protocol	9 dimensions	.96	Excellent
Expert Validation Checklist	25	.97	Excellent

Following content validation, the instruments were pilot tested with 30 mining students who shared characteristics with the target population to evaluate readability, comprehensibility, and internal consistency. Participants reported that the questionnaire items were clear, relevant, and appropriate for their academic context, leading to minor revisions that improved linguistic precision. Internal consistency was subsequently assessed using Cronbach's Alpha in IBM SPSS Statistics Version 29. The questionnaire demonstrated excellent reliability with an overall coefficient of $\alpha = .93$, while the five dimensions yielded coefficients ranging from $\alpha = .82$ to $.91$, indicating satisfactory to excellent internal consistency. These findings confirmed that the instrument was both reliable and suitable for measuring students' English learning needs in the present study.

Table 6: Reliability analysis results

Dimension	Number of Items	Cronbach's Alpha	Interpretation
Content Needs	8	.88	Good
Language Needs	10	.91	Excellent
Cognition	6	.85	Good
Culture/Context	6	.82	Good
Integration Needs	6	.89	Good
Learning Preferences	6	.87	Good
Overall Instrument	42	.93	Excellent

The reliability coefficients exceeded the recommended threshold of .70 for educational research (Creswell & Creswell, 2018), confirming that the questionnaire consistently measured students' perceptions and learning needs and was therefore suitable for the main study. To enhance the trustworthiness of the qualitative findings, member checking was conducted by returning interview summaries to selected participants for verification, while peer debriefing was undertaken throughout the coding and theme development process. In addition, methodological triangulation integrated questionnaire, interview, and expert validation data to explain quantitative patterns within their educational and professional contexts. This process strengthened the credibility and comprehensiveness of the findings, which subsequently informed the design principles and development of the deep-CLIL-based English for mining materials.

4. Results

4.1 Existing Exposure to English for Mining Content

The first finding revealed that the integration of mining-related content into English instruction remains limited. Although 58.5% of students reported that mining topics were regularly incorporated into English classes, a substantial proportion indicated that such integration occurred only occasionally or not at all.

These findings suggest that English instruction continues to emphasize general English rather than discipline-specific communication, limiting students' opportunities to develop the linguistic competencies required in professional mining contexts. The interview data reinforced this interpretation, with participants consistently describing a disconnect between the existing English curriculum and the communicative demands of the mining profession. They reported limited opportunities to engage with mining-related communication tasks, highlighting the need for contextualized ESP materials that better align language learning with authentic workplace practices.

One participant explained:

"The English course only repeats general English materials that we already learned in high school. There is almost no discussion about mining." AKL

Another participant shared a similar concern:

"Most materials are general grammar and daily conversation, while technical mining vocabulary is rarely discussed." BCG

A third participant further commented:

"I hope the English class includes technical reports, safety communication, and mining case studies because these are closely related to our future work." MA

Collectively, these responses indicated that the existing English curriculum did not adequately address the discipline-specific communication needs of mining students. The findings therefore reinforced the need for contextualized English for mining materials that integrate authentic workplace communication with disciplinary content.

4.1.1 Content needs

Students were asked to select 10 mining-related topics they considered most important for English learning.

Table 7: Priority mining topics for English materials

Topic	%
Mining Industry Overview	80.2
Mining Methods	74.5
Geological Exploration and Survey	70.8
Environmental Impacts of Mining	68.9
Heavy Equipment and Machinery	67.0
Occupational Safety and PPE	65.1
Mineral Processing	60.4
Drilling Techniques	58.5
Project Presentation	51.9
Blasting Operations	48.1

The findings indicated that students prioritized workplace-oriented mining topics, with mining industry overview (80.2%), mining methods (74.5%), and geological exploration (70.8%) emerging as the highest priorities. Notably, environmental sustainability (68.9%) ranked higher than several operational topics, suggesting that students viewed mining as encompassing both technical expertise and environmental responsibility. These findings highlight the need for English for mining materials that integrate authentic disciplinary content with sustainability issues to reflect the evolving competencies expected of mining professionals. The interview data reinforced this interpretation, as participants consistently emphasized the importance of learning English through authentic workplace communication, including technical documentation, operational procedures, and professional interactions commonly encountered in the mining industry.

One participant explained:

"I want to learn English that helps me understand safety procedures, heavy equipment, geological exploration, and technical reports because those are what we encounter in practice." HUI

Similarly, another participant stated,

"We need English materials about real mining activities, not only general English. Learning technical vocabulary and communicating in mining situations will be much more useful for our future jobs." RA

This concern was repeated by another student, who remarked,

"Most English classes still focus on grammar and everyday conversations. I hope the materials include mine planning, environmental management, and safety communication because these are closely related to our field." SHL

A fourth participant highlighted the importance of workplace communication by stating,

"During internships, we often read manuals and safety instructions in English. It would be helpful if these types of materials were introduced in class." MSR

The convergence between quantitative and qualitative findings demonstrates a strong need for authentic mining-related content.

4.1.2 Communication needs

The communication dimension investigated the English skills most needed for future mining careers.

Table 8: Priority language skills

Skill	%
Speaking in Technical Discussions	65.1
Reading Technical Documents	39.6
Listening to Instructions and Training	34.9
Writing Reports and Correspondence	27.4

Speaking emerged as the dominant language skill, selected by nearly two-thirds of the participants. The interview findings further explained this preference by revealing that students viewed speaking proficiency as essential for communicating in multilingual mining workplaces, particularly when interacting with foreign engineers, supervisors, and contractors.

One participant explained,

"There are many foreign workers in mining companies. If I cannot speak English, it will be difficult to communicate." DLI

Another participant emphasized the importance of spoken communication in daily professional activities:

"Speaking is important because I need to discuss technical issues, explain projects, and interact with foreign supervisors." TI

A third participant added,

"During field practice, we often need to ask questions, give instructions, and report work progress in English. That is why speaking is the most important skill for us." PIO

At the same time, several participants recognized that reading remained an essential skill because many technical manuals, standard operating procedures, geological reports, equipment specifications, and safety documents are written in English.

One participant noted,

"I also need good reading skills because most technical manuals and safety instructions are written in English." KHU

Collectively, these responses indicated that mining students viewed speaking and reading as complementary competencies required for effective professional practice. While speaking was considered crucial for workplace interaction, reading was regarded as equally important for understanding technical documentation and ensuring safe and efficient mining operations. These findings therefore suggested that English for mining materials should prioritize authentic

oral communication while simultaneously strengthening students' technical reading literacy.

4.1.3 Cognitive needs

The cognition dimension explored students' expectations for using English to develop higher-order thinking in mining contexts. Quantitative findings showed that 81.0% of participants perceived English learning as encouraging critical thinking, while 56.7% reported confidence in analyzing and explaining mining concepts in English, although 22.1% remained uncertain, indicating the need to strengthen students' cognitive engagement with discipline-specific content.

The interview findings reinforced this pattern, with participants consistently preferring authentic learning activities that required them to analyze mining problems, evaluate evidence, and apply disciplinary knowledge rather than memorize vocabulary or grammar. These findings highlighted the importance of designing English for mining materials that integrate critical inquiry and problem-solving with language learning, consistent with the pedagogical principles underpinning the proposed deep-CLIL framework.

One participant explained:

"I prefer discussing real mining cases because they make me think about the problem and how to explain the solution in English." KHU

Another participant stated,

"Instead of memorizing technical terms, I want to analyze accident cases and discuss how similar problems can be prevented." TLM

A third participant emphasized,

"Learning becomes more meaningful when we solve mining-related problems, evaluate environmental impacts, and explain our ideas in English." SAN

These responses indicated that students expected English learning to foster critical thinking alongside language development. The findings therefore suggested that English for mining materials should incorporate higher-order learning activities, such as problem-solving, case analysis, decision-making, environmental impact evaluation, and risk assessment, to prepare students better for authentic academic and professional challenges.

4.1.4 Contextual and Workplace Needs

The results revealed that only 20% of participants perceived the existing English materials as highly relevant to mining industry needs, whereas 41% considered them only moderately relevant. At the same time, 63.8% reported encountering situations during internships, field projects, seminars, or industrial visits where English was required. These findings suggested that students experienced a noticeable gap between classroom instruction, and the language demands of professional practice. The interview data further illustrates this gap.

One participant reflected:

"When I was doing my internship, some senior managers communicated in English, and that made me realize how important English is in mining." PTG

Another participant explained,

"Many technical documents and software manuals are written in English, so we need to understand them before we can use the equipment properly." BBG

A third participant highlighted the mismatch between classroom learning and workplace expectations:

"At university, we mostly learn general English, but during my internship I had to read technical reports and communicate with engineers using mining terminology." UGL

Another participant added,

"I realized that English is not only needed for conversation but also for understanding safety procedures, operating manuals, and technical presentations." TIU

Taken together, these responses indicated that students frequently encountered authentic English communication during industrial experiences but perceived a mismatch between the language demands of the workplace and the English instruction they had received. These findings highlighted the importance of developing English for mining materials that incorporate authentic workplace communication, technical documentation, and discipline-specific tasks to prepare students better for professional practice.

4.1.4 Integration needs

An overwhelming 97.1% of participants supported integrating English with mining content, while 93.3% believed that project-based learning would enhance their understanding. The interview findings reinforced these quantitative results, with participants consistently emphasizing that English was more meaningful when embedded in authentic mining tasks.

As one participant explained,

"I learn English more easily when we work on mining projects because the language is directly connected to what we study" (SAN).

Similarly, another participant noted,

"Instead of learning vocabulary lists, I prefer solving real mining problems and discussing the solutions in English" (P9).

A third participant added,

"Project-based learning helps us understand both the mining concepts and the English needed to explain them. It feels more practical than learning English separately" (MA).

Collectively, these findings indicated that students prefer integrated learning experiences in which English functions as a medium for disciplinary learning, authentic problem-solving, and professional communication, providing strong empirical support for the proposed deep-CLIL framework.

4.2 Development of the Deep-CLIL Framework

Based on the needs analysis findings, a new framework named deep-CLIL was developed. The framework extended Coyle's 4Cs model by integrating deep learning principles and workplace-oriented ESP practices.

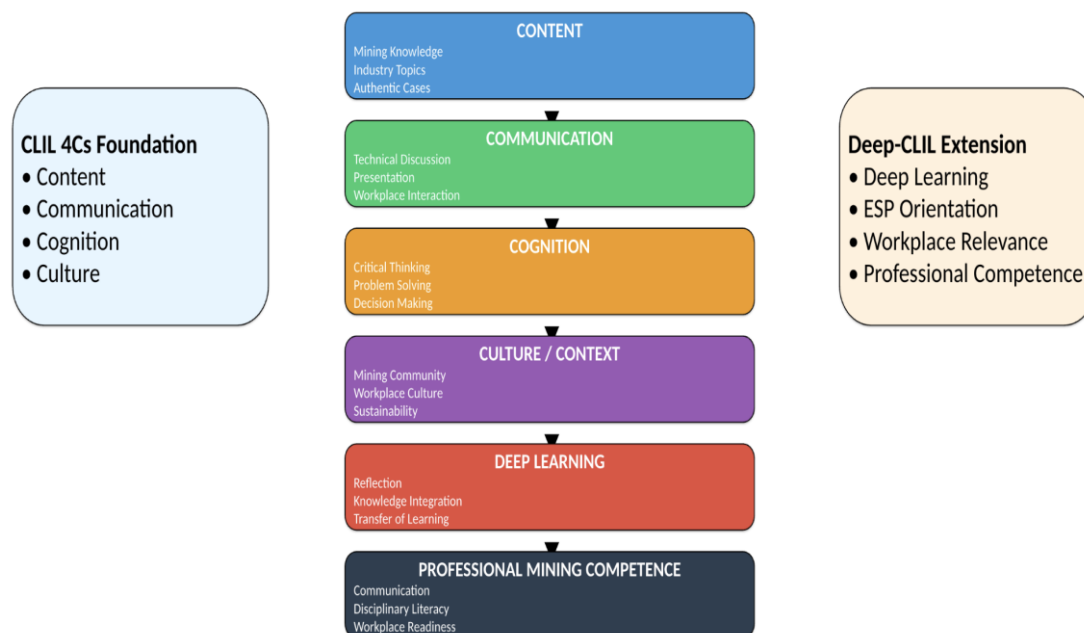


Figure 2: Deep-CLIL framework

Based on the quantitative and qualitative needs analysis, five design principles were identified to guide the development of the deep-CLIL-based English for mining materials. First, authentic mining content emphasizes the inclusion of topics, terminology, and learning resources that reflect real mining practices, enabling students to connect language learning with their disciplinary knowledge. Second, technical communication development focuses on strengthening students' ability to communicate effectively in professional mining contexts through speaking, listening, reading, and writing tasks involving technical reports, safety procedures, presentations, and workplace interactions.

Third, critical and analytical thinking promotes higher-order cognitive skills by engaging students in problem-solving, case analysis, decision-making, and the evaluation of mining-related issues. Fourth, industry contextualization ensures that learning activities are situated within authentic mining environments, including operational processes, environmental sustainability, occupational safety, and professional communication. Fifth, project-based professional tasks encourage students to apply both disciplinary knowledge and English language

skills through collaborative projects that simulate real workplace challenges, thereby fostering communication, teamwork, and workplace readiness.

4.3 Development of English for Mining Materials

The developed instructional materials comprised 10 sequential units addressing core domains of mining education, from introductory concepts to specialized topics, including mining methods, geological exploration, drilling, blasting, heavy equipment, mineral processing, mine safety, environmental management, and technical reporting (Table 9).

Table 9: Structure of the developed materials

Unit	Topic
1	Introduction to Mining Industry
2	Mining Methods
3	Geological Exploration
4	Drilling Operations
5	Blasting and Fragmentation
6	Heavy Equipment
7	Mineral Processing
8	Mine Safety
9	Environmental Management
10	Technical Reports and Project Presentations

Guided by the deep-CLIL framework, each unit integrated discipline-specific vocabulary, authentic texts, case studies, collaborative inquiry, reflective learning, project-based activities, and performance-based assessment to promote the simultaneous development of disciplinary knowledge, language proficiency, higher-order thinking, and professional communication. Rather than treating English as an isolated subject, the materials embedded language learning within authentic mining practices that required students to analyze workplace problems, evaluate evidence, communicate solutions, and collaborate in discipline-specific tasks.

For example, the mine safety unit required students to investigate a workplace accident involving improper use of personal protective equipment (PPE), identify safety violations, propose preventive measures, and present evidence-based recommendations in English. This design exemplifies how the deep-CLIL framework operates the integration of content, communication, cognition, and contextualized professional engagement, thereby preparing students for authentic communication and problem-solving in mining practice.

4.4 Expert Validation Results

Three experts evaluated the developed materials using the expert validation checklist. As shown in Table 10 the evaluation dimensions achieved a “very valid” rating, indicating that the developed materials were considered highly appropriate in terms of content quality, language use, deep-CLIL alignment, learning design, and practicality.

Table 10: Expert validation results

Dimension	Mean
Content Quality	4.82
Language Quality	4.76
Deep-CLIL Integration	4.91
Instructional Design	4.79
Practicality	4.73
Overall Mean	4.80

The experts particularly appreciated the integration of mining content with communication and higher-order thinking tasks, emphasizing its relevance to both educational and professional contexts.

One expert commented,

"The materials successfully bridge the gap between mining knowledge and English communication skills. The integration is highly relevant to current industry needs." MFH

Another expert highlighted the authenticity of the learning activities:

"The project-based tasks encourage deeper engagement and reflect authentic professional practices." FRD

Collectively, the expert feedback indicated that the proposed deep-CLIL materials were pedagogically sound, contextually relevant, and suitable for implementation in English for mining courses.

4.5 Characteristics of the Final Product

The final product was characterized by its discipline-specific orientation, communication-centered pedagogy, and integration of higher-order thinking. All instructional units were derived from authentic mining contexts identified through the needs analysis, ensuring close alignment with students' academic and professional requirements. Learning activities emphasized technical discussions, presentations, collaborative inquiry, workplace simulations, and problem-solving tasks that required students to analyze evidence, evaluate alternatives, and communicate solutions in English.

To enhance workplace relevance, the materials incorporated authentic technical documents, safety procedures, environmental reports, and professional communication tasks. Most importantly, each unit systematically integrated the five dimensions of the deep-CLIL framework of content, communication, cognition, culture/context, and deep learning thereby supporting the simultaneous development of English proficiency, disciplinary understanding, critical thinking, and professional competence in mining education.

5. Discussion

The present study developed the deep-CLIL-based English for mining materials by integrating the complementary principles of ESP, CLIL, and deep learning. The findings support ESP research emphasizing that language instruction should be grounded in learners' disciplinary and professional needs (Xia & Li, 2026) and reinforce CLIL studies showing that authentic integration of content and language enhances disciplinary understanding and meaningful communication (Beaudin, 2022; Hu et al., 2025; Rakhmasari & Pratiwi, 2025). They also align with deep learning research highlighting the role of critical inquiry, problem-solving, and knowledge integration in higher education (Alamoudi & Butt, 2026). Extending these complementary perspectives, the proposed deep-CLIL framework provides a unified pedagogical model that simultaneously promotes disciplinary learning, professional communication, and higher-order thinking in English for mining education.

5.1 From General English to Contextualized English for Mining

One of the key findings of this study is students' strong preference for contextualized English learning that reflects authentic mining knowledge and professional practice. Rather than viewing English as a general academic subject, participants expected learning experiences aligned with their disciplinary specialization and workplace demands. This finding supports previous ESP research showing that learners perceive general English as insufficient for discipline-specific communication and prefer contextualized materials grounded in authentic professional practice (Xia & Li, 2026; Swales, 2020).

It also reinforces the ESP principle that instructional content should be derived from learners' academic and professional needs to enhance engagement, motivation, and workplace readiness (Banegas et al., 2025; Girón-García & Fortanet-Gómez, 2023; Nguyen et al., 2025; Hidayati et al., 2025). From a CLIL perspective, the findings confirm that disciplinary content provides an authentic context for meaningful language learning, enabling students to use English as a medium for knowledge construction rather than merely acquiring linguistic forms (Coyle & Meyer, 2021; Hu et al., 2025; Kos & Bergner, 2026; Rakhmasari & Pratiwi, 2025).

Extending these complementary perspectives, the proposed deep-CLIL framework integrated ESP, CLIL, and deep learning by embedding critical inquiry, authentic problem-solving, and reflective learning within discipline-specific instruction. Consequently, the developed English for mining materials fostered not only professional communicative competence but also the higher-order thinking and workplace readiness required in contemporary mining practice.

5.2 Speaking as Professional Participation and Workplace Readiness

Another important finding is the prominence of speaking as the language skill most closely associated with students' future professional roles. Participants emphasized the importance of oral communication for interacting with foreign supervisors, collaborating in multinational teams, and participating in technical

discussions, highlighting the growing internationalization of the mining industry. Accordingly, English for mining instruction should prioritize authentic speaking activities, such as technical presentations, workplace discussions, safety briefings, project meetings, and problem-solving tasks. This finding is consistent with recent ESP research identifying oral communication as a key competency for technical professionals and an important determinant of employability in multicultural workplaces (Girón-García & Fortanet-Gómez, 2023; Hidayati et al., 2025). It also reinforces the communicative dimension of CLIL, which conceptualizes language as both the medium and the outcome of disciplinary learning through authentic interaction (Rakhmasari & Pratiwi, 2025).

Extending previous ESP and CLIL scholarships, the proposed deep-CLIL framework integrates authentic workplace communication with disciplinary content and higher-order thinking, enabling students to simultaneously develop speaking proficiency, disciplinary understanding, and professional readiness for mining contexts.

5.3 The Emergence of Deep Cognitive Needs in English Learning

The most theoretically significant finding is that students expected English learning to foster higher-order thinking alongside language development. Rather than focusing solely on linguistic knowledge, participants emphasized critical inquiry, problem-solving, and the application of disciplinary knowledge in authentic mining contexts. This finding supports deep learning research demonstrating that meaningful learning emerges through conceptual understanding, knowledge integration, and cognitively demanding tasks (Alamoudi & Butt, 2026; Zhang et al., 2025). It also reinforces CLIL scholarship, which positions language as a medium for disciplinary inquiry and knowledge construction (Hu et al., 2025; Rakhmasari & Pratiwi, 2025), while aligning with evidence that inquiry-based and project-oriented learning enhances critical thinking, learner engagement, and disciplinary literacy (Tai et al., 2025; Kos & Bergner, 2026).

The interview findings further confirmed that students learned more effectively through authentic problems, environmental case studies, safety investigations, collaborative inquiry, and project-based activities that connected language learning with disciplinary understanding, consistent with research highlighting the benefits of authentic and inquiry-based learning for conceptual understanding and knowledge transfer (Kaiypova et al., 2025; Ma et al., 2025).

Collectively, these findings suggest that English for mining should extend beyond technical vocabulary to integrate disciplinary knowledge, authentic communication, and higher-order thinking. Extending recent ESP, CLIL, and deep learning scholarship (Alamoudi & Butt, 2026; Hu et al., 2025; Xia & Li, 2026; Zhang et al., 2025), the proposed deep-CLIL framework provides a unified pedagogical model for developing language proficiency, disciplinary understanding, and transferable professional competencies.

5.4 Authentic Contexts as Catalysts for Meaningful Learning

Another important finding concerns the role of authentic contexts in promoting meaningful language learning. Both the quantitative and interview findings indicate that students value English instruction that reflects the communicative demands of the mining profession rather than general language use. Participants reported encountering English-language manuals, technical reports, safety documentation, software interfaces, and interactions with industry personnel during internships and field experiences, yet they perceived existing English courses as providing limited opportunities to engage with such authentic materials.

This finding is consistent with recent ESP research emphasizing that contextualized instruction enhances learners' perceived relevance, disciplinary engagement, and professional preparedness (Swales, 2020; Xia & Li, 2026). CLIL studies demonstrate that authentic disciplinary contexts facilitate the meaningful integration of language and content by enabling learners to construct knowledge through professional communication (Hu et al., 2025; Rakhmasari & Pratiwi, 2025). Likewise, research on CLIL and ESP highlights that authentic learning environments encourage learners to apply language in meaningful situations while integrating disciplinary knowledge with communication skills (Kos & Bergner, 2026; Pérez-Cañado, 2021).

Extending this body of research, the present study suggests that authenticity functions not merely as a contextual feature but also as a cognitive catalyst. By engaging students with real mining accidents, environmental issues, geological reports, and workplace scenarios, authentic tasks require them to interpret information, evaluate evidence, justify decisions, and communicate solutions, thereby fostering the deep learning processes that underpin the proposed deep-CLIL framework.

5.5 Students' Strong Support for Integrated Learning and the Emergence of Deep-CLIL

Students repeatedly emphasized that language and mining content should not be taught separately because professional communication always occurs within specific disciplinary contexts. Participants expressed a desire for learning activities that simultaneously develop technical understanding, communication skills, and workplace readiness. These findings are consistent with recent CLIL research demonstrating that integrating language and content promotes meaningful disciplinary learning and communication (Hu et al., 2025; Kos & Bergner, 2026). However, the present study suggests that content-language integration alone may not fully address the demands of professional education, as students also expect learning experiences that foster critical inquiry, reflection, authentic problem-solving, and workplace engagement. This perspective is supported by contemporary deep learning research, which emphasizes higher-order thinking as a key outcome of meaningful learning in higher education (Alamoudi & Butt, 2026; Zhang et al., 2025).

Building on these complementary perspectives, the proposed deep-CLIL framework extends the traditional CLIL model by integrating deep learning principles with ESP-based needs analysis. Informed by students' preferences for contextualized content, workplace communication, critical thinking, and project-based learning, the framework provides a context-responsive instructional model that supports disciplinary knowledge, professional communication, and higher-order thinking in English for mining.

5.6 Theoretical and Practical Contributions of Deep-CLIL

The findings contribute theoretically by extending scholarship ESP, CLIL, and deep learning through a unified framework for discipline-specific materials development. While ESP research has primarily emphasized needs analysis and profession-oriented language instruction (Dudley-Evans & John, 1998; Xia & Li, 2026), CLIL has focused on integrating content and language learning to improve language achievement and content acquisition (Coyle et al., 2010; Hu et al., 2025), and deep learning research has examined cognitive engagement, critical thinking, and meaningful learning in higher education (Alamoudi & Butt, 2026; Biggs & Tang, 2011; Xia & Li, 2026).

Building on these complementary perspectives, the present study conceptualizes deep-CLIL as an extension of conventional CLIL by explicitly positioning deep learning as the mechanism linking language development, disciplinary knowledge, higher-order thinking, and workplace competence. This contribution responds to recent calls for more cognitively engaging approaches to professional language education and demonstrates how CLIL can be adapted to specialized disciplinary contexts.

From a practical perspective, the findings indicate that English for mining instruction should integrate authentic disciplinary content, collaborative inquiry, project-based learning, and workplace communication rather than focusing primarily on grammar. This interpretation is consistent with evidence showing that contextualized ESP and CLIL approaches strengthen disciplinary literacy, learner engagement, and meaningful language use (Hu et al., 2025; Xia & Li, 2026). Although recent meta-analytic evidence suggests that CLIL's effects on content learning depend on instructional design and implementation quality (Lee et al., 2025), the proposed deep-CLIL framework addresses this challenge by integrating ESP, CLIL, and deep learning into a coherent instructional model that provides practical guidance for curriculum and materials development in technical and professional higher education.

6. Conclusion

This study developed and validated deep-CLIL-based English for mining materials to address the academic and professional language needs of mining students. The findings demonstrated that learners expected English instruction to integrate authentic mining contexts, disciplinary knowledge, professional communication, and higher-order thinking rather than focusing solely on general language proficiency. Responding to these needs, the proposed deep-CLIL framework extended conventional CLIL by explicitly incorporating deep learning

principles into a unified pedagogical model that integrates content, communication, cognition, and contextualized professional engagement. Expert validation confirmed the pedagogical quality, contextual relevance, and implementation feasibility of the developed materials.

Theoretically, the study advances CLIL and ESP scholarship by demonstrating how deep learning principles can strengthen discipline-specific materials development, while practically providing a validated framework that can guide curriculum and instructional design in technical and vocational higher education. Although the materials were validated by experts, they have not yet been implemented in authentic classroom settings. Future research should, therefore, investigate the effectiveness of the deep-CLIL framework in improving language proficiency, disciplinary competence, critical thinking, and workplace readiness across diverse ESP disciplines and educational contexts.

7. Limitations, Future Implications, and Recommendations

Despite these contributions, the study has several limitations. The materials were validated through expert review but were not implemented in a large-scale classroom intervention. Consequently, the effectiveness of the deep-CLIL materials in improving students' language proficiency, disciplinary literacy, critical thinking, and workplace communication competence remains to be empirically examined. Future research may, therefore, investigate the implementation of deep-CLIL in different educational contexts, compare its effectiveness with conventional ESP approaches, and explore its applicability in other professional disciplines such as engineering, environmental science, health sciences, and vocational education.

Conflict of Interest

The authors declared no conflicts of interest related to the research, authorship, or publication of this article.

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