Journal of Management Practices, Humanities and Social Sciences

Vol 10 Issue 4 pp. 689-701

https://doi.org/10.33152/jmphss-10.4.11



ORIGINAL CONTRIBUTION

Enhancing The Professional Competences of Pre-Service Biology Teachers Through CLIL

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Abstract— It has become more crucial than ever to prepare future educators to adapt to the shifting demands of the classroom as educational methods continue to change. Developing a solid grasp of biological principles is only one aspect of this training for pre-service biology instructors. Additionally, they must learn how to effectively convey scientific information, choose effective teaching techniques, and design classrooms that accommodate students of various skill levels and backgrounds. A useful strategy for meeting these needs is Content and Language Integrated Learning (CLIL), which combines subject study with the development of foreign languages. With this method, aspiring biology instructors can improve their subject-matter expertise while receiving hands-on experience with language as a teaching and learning tool. The CLIL-based training was given to 120 pre-service biology instructors as part of the project. The effectiveness of the intervention was assessed by comparing pre-test, during-test, and post-test results using Meltzer's Gain Index. The obtained gain values provided a quantitative indication of the improvement in the development of communicative, methodological, psychological-pedagogical, and subject-specific competences. The results of the study reveal improvements in communicative, methodological, and psychological-pedagogical competencies, as well as partial improvement in subject-specific competence. The study highlights that CLIL is a successful method for preparing biology instructors so they can instruct in diverse and multilingual classrooms. The findings demonstrate how important it is to include CLIL in teacher education programs in order to encourage more thorough and internationally oriented professional development.

Index Terms— Pre-service biology teachers, CLIL, 4C model, Professional competences, The Likert scale, Meltzer's gain index classification

Received: 23 April 2026; **Accepted:** 25 June 2026; **Published:** 19 July 2026

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Introduction

Expectations for modern educational institutions are always evolving, particularly in the field of science education. Teachers of biology, who play a crucial role in helping pupils understand the natural world, must have both significant subject-matter understanding and the ability to instruct in a variety of languages and diverse contexts. Innovative teaching strategies like Content and Language Integrated Learning (CLIL) have gained popularity as a result (Ambreen, 2026; Kim & Graham, 2022). Modern cultures depend heavily on science and education, especially in a globe that is becoming more interconnected by the day. In addition to imparting knowledge and useful skills, education promotes critical thinking, flexibility, and creativity, all of which advance society. As society continues to change due to technology advancements, cultural exchanges, economic growth, and demographic shifts, educational institutions are under increasing pressure to prepare students for these shifting circumstances. In order to meet these demands, teaching strategies must go beyond traditional ways and assist aspiring professionals in acquiring the skills, knowledge, and adaptability required for their careers.

Innovative teaching techniques are becoming a crucial component of initiatives to raise educational standards and enhance student learning. Interdisciplinary approaches and student-centered methods can increase opportunities for active engagement, boost students' motivation, and aid in their academic growth. Content and Language Integrated Learning (CLIL) is one strategy that has garnered a lot of interest in international education. David Marsh used the term CLIL in 1994 to refer to a method of teaching that combines subject matter with a second language. CLIL integrates disciplinary knowledge and language acquisition into a shared learning process, enabling students to acquire both foreign language fluency and subject-specific understanding at the same time (Elmadhi, 2026; Nartayeva et al., 2024).

The article's main goal is to find out how pre-service biology teachers' professional competencies might be improved through Content and Language Integrated Learning (CLIL). The essay focuses on the particular abilities needed to teach well in multilingual settings, looks at CLIL approaches, and suggests ways to include this approach into teacher education programs.

The following are the objectives:

1. Conduct a literature review on the topic of CLIL and identify its characteristics and specific features.

2. To outline the specific professional competences that pre-service biology teachers need to develop in order to teach effectively in CLIL setting (Scherzinger & Brahm, 2023).

3. Conduct experimental testing on the development of professional competencies for pre-service biology teachers based on CLIL, specifically focusing on subject-specific, communicative, methodological, and psychological-pedagogical competencies.

By analyzing the growth of these four related domains in a CLIL-based teacher-training setting, the current study fills this gap. Instead of concentrating only on language proficiency or subject learning outcomes, the study's distinctiveness resides in its thorough attention on the professional competence of aspiring biology teachers and in the experimental measurement of competency growth through CLIL (Tyutenova et al., 2020).

Literature Review

Almost every facet of contemporary society has been impacted by the significant changes that have occurred in the world during the last several decades. The Internet's extensive growth and the growing globalization of social, political, and economic activities are two of the most important changes (D. Hu et al., 2025; Lu et al., 2025). Additionally, these changes have altered educational systems, setting new standards for the delivery of knowledge and the preparation of students for both academic and professional life (Marsh, 2002). Teaching strategies that incorporate foreign languages into the learning process are receiving more and more attention in various European nations. These methods enable students to use a foreign language as a way to gain knowledge and build subject-related abilities, in contrast to traditional language training, where mastering the language itself is the main goal (Juan-Garau & Salazar-Noguera, 2015).

Kazakhstan has also taken action to adapt to national priorities while bringing its educational system into line with more general international changes. The nation created the vision for the Development of Foreign Language Education in the Republic of Kazakhstan based on growing practices in international education, the national vision for educational development, and state education policy. This framework was intended to establish greater consistency and continuity in foreign language proficiency across different stages of education. It also emphasized the need to modernize foreign language teaching through a coordinated approach that reflects the country's language policy and long-term educational objectives (Papaja, 2014).

These models reflect the flexibility of CLIL in accommodating different levels of language proficiency, subject matter complexity, and institutional goals, ensuring that both content learning and language development are addressed effectively. Here are some of them.

Soft and Hard CLIL

Soft CLIL is a language-driven learning. This methodology uses disciplinary subjects as tools to help learners acquire the target language. Gaining in-depth subject knowledge is secondary to improving language competency, which is the main goal of soft CLIL. It is frequently used in language

classes to increase students' vocabulary, grammar, and communication skills without requiring the same level of topic comprehension as more content-driven CLIL techniques (Holmes, 2017).

Hard CLIL

Hard CLIL refers to a subject-driven learning where the primary focus is on content learning. In this model, students are taught academic subjects exclusively through a foreign language. The focus is on developing a thorough grasp of the subject, and language acquisition happens organically as a result of interacting with the material. In a challenging CLIL biology course, students learn complex scientific terms, theories, and concepts in the target language, with a concentration on biology curriculum mastery rather than language training.

In the context of Content and Language Integrated Learning (CLIL), pre-service biology teachers' psycho-pedagogical competence entails a combination of pedagogical and psychological skills that enable them to recognize and address students' mental, emotional, and developmental needs throughout the learning process (Jayanti et al., 2025). This competence enables teachers to foster a supportive and positive educational environment by acknowledging students' individual differences, cognitive growth, and socio-emotional factors that impact their learning. These main components are identified as essential elements of psycho-pedagogical competence:

1. Psychological and pedagogical literacy as stated by Shulman (1987) 1) is commonly regarded as general professional knowledge about how students learn and develop, encompassing cognitive, emotional, and social dimensions. It involves the ability to apply psychological theories to develop effective teaching strategies and create supportive classroom environments, as well as recognizing and addressing the diverse backgrounds, abilities, and learning styles of students to offer personalized support.

2. Psychological-pedagogical skills according to Poveda-Garcia-Noblejas and Antropova (2024) 1) encompass a variety of skills that are crucial for effectively teaching the subject and supporting student learning and development. These skills generally include the ability to create a structured and positive learning environment, manage student behavior, and facilitate group work and discussions; the ability to recognize and regulate one's own emotions as well as those of students, promoting a supportive and empathetic classroom atmosphere, etc.

3. Guskey (2002) that the professionally significant personal qualities of pre-service biology teachers, particularly within the context of CLIL are essential for delivering effective science education and igniting student interest in biological subjects. These qualities are crucial for engaging students, fostering inquiry-based learning, and developing a greater appreciation for the natural world. Important personal attributes for biology teachers encompass curiosity and enthusiasm for science, analytical thinking, creativity, a commitment to lifelong learning, and an interdisciplinary approach, among others.

Therefore, the professional-pedagogical competence of pre-service biology teachers in the context of CLIL is a comprehensive collection of qualities that reflects the individual's personal, social, and moral experiences, as well as their readiness to develop and enhance their professional practice and their conscious mastery of linguistic tools for conveying meaning.

The reviewed literature demonstrates that CLIL has been conceptualized from different but complementary perspectives. Pittas and Tompkins (2024) emphasize integrating content, communication, cognition, and culture, while H. Hu et al. (2023) and Llinares et al. (2012) further highlight the different functions of language required to learn and communicate subject content. Satayev et al. (2025), by contrast, differentiate between soft and hard CLIL based on the relative importance of language and subject matter. These viewpoints show that CLIL's efficacy depends on the interplay of content knowledge, language use, cognitive engagement, and pedagogical methods rather than being reduced to either foreign-language instruction or teaching a subject through another language. However, research indicates that the ratio of these components may change depending on the educational setting, language competency of students, and subject-specific needs (Mehisto et al., 2008; Papaja, 2014; Renau, 2019).

Despite these complementary viewpoints, the examined studies offer less clarity on how CLIL might be used systematically to build the full spectrum of professional competences needed for pre-service biology teachers. Existing literature has addressed CLIL methodology, language development, pedagogical knowledge, and the integration of content and language, but these dimensions are often considered separately rather than as interconnected components of professional teacher competence. This issue is particularly important in biology education, where teachers need to combine specialized scientific knowledge, subject-specific academic language, appropriate teaching methods, and the ability to respond to students' psychological and pedagogical needs. Therefore, the present study focuses on the combined development of Subject-Specific, Communicative, Methodological, and Psychological-Pedagogical Competences through CLIL-based teacher training (Umbar et al., 2024).

Based on the reviewed literature, the study hypothesized that CLIL-based training would contribute to the development of the professional competences of pre-service biology teachers. More specifically, it was expected that the training would improve their Communicative, Methodological, Psychological-Pedagogical, and Subject-Specific Competences, with the greatest improvements expected in areas directly related to the integration of language and teaching methodology. After conducting a thorough literature review on the research topic, we concluded that the key professional competencies are Subject-Specific, Communicative, Methodological, and Psychological-Pedagogical.

Methods and Material

A one-group pre-test, during-test, and post-test design was used in the study. Since the study did not contain a control group, the observed changes cannot be solely attributed to the CLIL intervention because other factors, such as students' natural development, the effects of testing,

and concurrent courses, may have also played a role. Therefore, the main goal of the study was to look at how the pre-service biology teachers' professional competency indicators changed during the course of the CLIL-based training.

The first diagnostic tool used to determine the participants' perceived level of professional competence across the four competency domains was a Likert-scale questionnaire. The participants completed a year-long CLIL-based training program after the initial survey. The competency scoring criteria outlined below were then used to evaluate professional competence at three measurement points: Pre-test, during-test, and post-test. These scores were treated as the primary quantitative indicators of changes in professional competence because they were used to compute the normalized gain.

The frameworks put out by H. Hu et al. (2023), Pittas and Tompkins (2024), and Shulman (1987) and Shayakhmetova (2019) were among the reviewed literature on CLIL, teacher professional competence, and pedagogical subject knowledge that served as the basis for the development of the questionnaire items and competency indicators. The items were aligned with the four competency areas examined in the study: Subject-Specific, Communicative, Methodological, and Psychological-Pedagogical Competence. The present study did not conduct formal reliability testing, such as Cronbach's alpha, and acknowledges this as a limitation of the measurement procedure.

The statistical analysis in this study was primarily descriptive and included the calculation of percentage distributions, competency scores, and normalized gain values based on pre-test, during-test, and post-test results. Inferential statistical tests, such as t-tests, p-values, and confidence intervals, were not conducted. Therefore, the findings should be interpreted as descriptive evidence of changes in professional competence rather than as evidence of statistically significant differences.

Findings and Discussion

In our survey, students from the 3rd year of the specialty 6M01505 - Training of Biology Teachers, Faculty of Natural Sciences of Zhanibekov University, South Kazakhstan participated. The total number of respondents was 120 people.

The survey consisted of 4 Sections and 8 statements, and students were required to select one response ("Strongly Agree", "Agree", "Neutral", "Disagree", or "and Strongly Disagree").

Section 1 "Enhancing Subject-Specific Competence" included 2 statements:

1) I possess a strong grasp of fundamental biological concepts.

2) I constantly stay up to date on the most recent advancements in biology.

We can evaluate pre-service biology instructors' confidence in their knowledge by asking them to rate how well they understand key biological concepts. This self-assessment provides insightful information on how ready they believe they are to instruct the subject. The answers assist in creating a baseline assessment of pre-service teachers' material knowledge, which enables educators to comprehend the cohort's present level of understanding.

Following data collection, the survey produced the following findings.

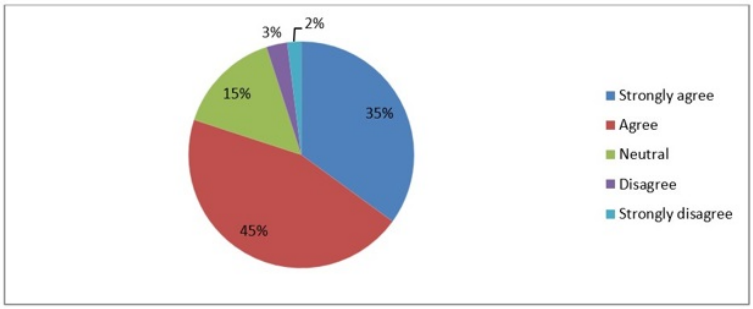


Fig. 1 *I have a solid understanding of basic biological concepts*

Students responded to the statement, "I have a solid understanding of basic biological concepts": 35% said they "strongly agree," demonstrating their command of scientific jargon, understanding of its significance, and confidence when using biological topics in their presentations. 45% of respondents selected "Agree," indicating that while they have a solid grasp of a variety of words and concepts, they are still learning the particulars of biological science, depending on the discipline. 15% of students selected "Neutral", indicating they are still in the process of studying biology as a science and have not yet mastered a sufficient amount of the necessary scientific terminology and information required for professional work. 3% of respondents chose "Disagree", which suggests difficulties in understanding terms and scientific categories. Finally, 2% of students responded "Strongly disagree", meaning they have a very vague understanding of biological concepts and categories.

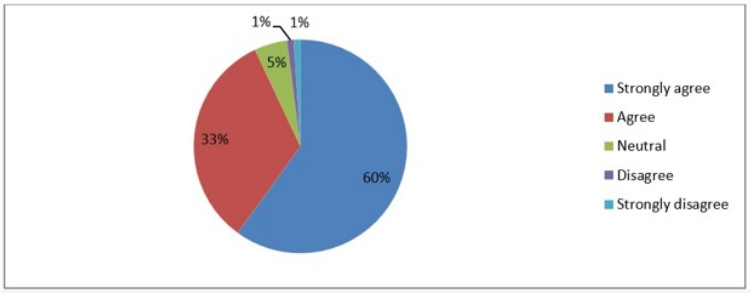


Fig. 2 *I regularly stay updated on current developments in the field of biology*

According to the results for the statement "I regularly stay updated on current developments in the field of biology", it was found that most 3rd- and 4th-year students 65% answered "Strongly agree", consistently showing interest in new trends in the field of biology, reading additional literature, and staying informed about the latest scientific advancements. Another 33% of students chose "Agree", indicating that they are also interested in new developments in biology, but unfortunately not regularly. Meanwhile, 5% of students who responded "Disagree" rely on university professors to learn about new advances and occasionally explore them on their own. Lastly, 1% of students are either not interested at all or very rarely show interest.

Section 2, "Enhancing Communicative Competence," included the following statements, namely:

1. I am confident in my ability to discuss biological issues in English.
2. I can effectively integrate language learning strategies into my biology lessons.

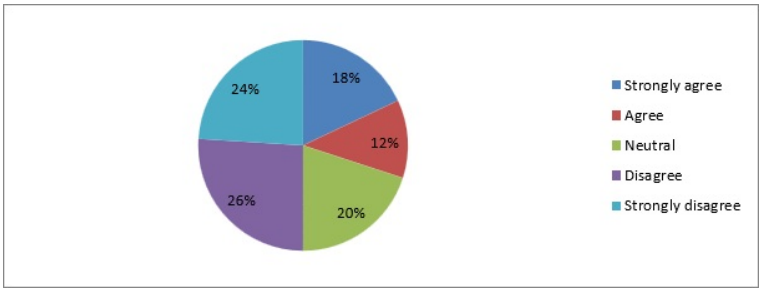


Fig. 3 *I am confident in my ability to discuss biological issues in English*

The results for the statement "I am confident in my ability to discuss biological topics in English" were fairly expected, as not all pre-service biology students have a high enough level of English proficiency (B2+ and C1). Only 2 groups in the 3rd year and 2 groups in the 4th year meet this level. In total, 56 out of 120 students have English proficiency at the B2+ and C1 levels. As a result, only 18% of students indicated that they are ready to discuss biological issues in English and express their thoughts freely in both oral and written form. 12% of students also expressed their willingness to participate in discussions on the subject. 20% of students remained "neutral", 26% responded "Disagree" and stated that they are not ready to participate in discussions due to an insufficient level of English proficiency. In comparison, 24% are completely unwilling to teach biology in English, preferring to teach only in their native language.

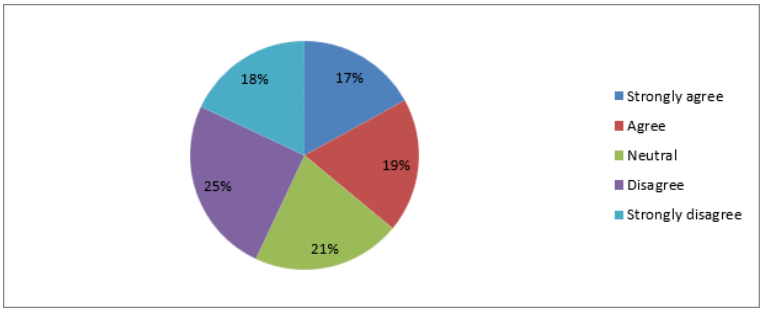


Fig. 4 *I can effectively integrate language learning strategies into my biology lessons*

The findings can be summarized as follows. As noted earlier, not all students have the English proficiency needed to teach biology in English while also teaching English through biological content. Consequently, the results were somewhat low. In biology classes, only 17% of

students said they were prepared to use language learning techniques. In contrast, 19% of respondents said they would be open to implementing language-learning techniques in biology classes.

Furthermore, 21% of respondents had a neutral opinion, suggesting that they are typically amenable to incorporating linguistic tactics into biology lessons. The majority of students lack the skills to apply language-teaching methods to both English language instruction and English-taught biology. The figures show that 25% of students selected ”Disagree,” while 18% selected ”Strongly disagree.”

Therefore, the survey results suggest that not all pre-service biology teachers possess a high level of English proficiency, indicating that their communicative competence is insufficiently enhanced, which affects their ability to teach biology in English.

Section 3: Methodological Competence also comprised two statements:

1. I think I am ready to use a CLIL approach when teaching biology.
2. I feel more confident teaching biology in a bilingual environment when I use a CLIL method.

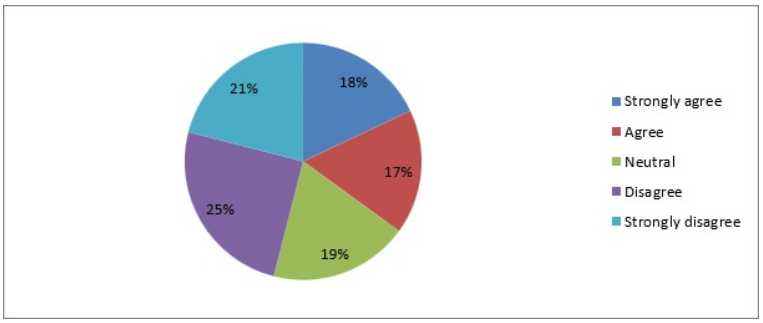


Fig. 5 *I think I am ready to use a CLIL approach when teaching biology*

The results showed that, in response to the statement, ”I feel well-prepared to teach biology using a CLIL approach,” 18% of students said they were prepared to teach biology using the CLIL approach, and another 17% expressed a comparable level of confidence by choosing ”Agree.” 19% of students adopted a ”Neutral” position, indicating that they are still unsure about their language proficiency and their capacity to apply CLIL techniques in biology classes. A noteworthy 25% of respondents ”Disagreed,” indicating that many students are not yet ready to teach biology in English and are unsure of the objectives, tactics, and techniques required to create the four Cs of CLIL. Additionally, 21% of students said they were totally unqualified to teach biology in English.

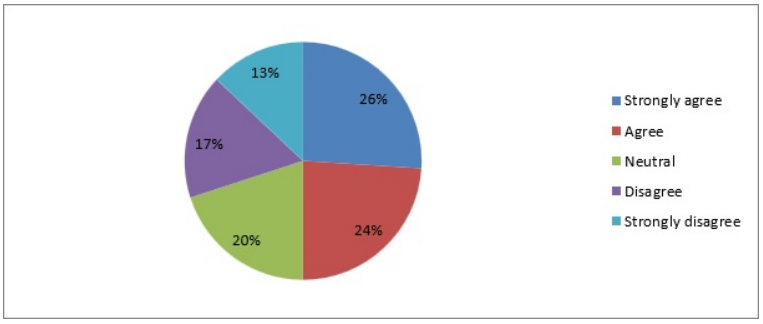


Fig. 6 *I feel more confident teaching biology in a bilingual environment when I use a CLIL method*

”A CLIL approach increases my confidence in teaching biology in a bilingual setting” yielded generally positive results. The fact that 26% of respondents chose ”Strongly agree” suggests that pre-service teachers are fairly prepared to teach biology in a bilingual setting using both English and their home tongue. Additionally, 24% of students said they were confident in their capacity to instruct biology in both languages. The native language helps clarify biological concepts when it becomes challenging to explain them in English. Regarding teaching biology in a multilingual setting, 20% of respondents said they had no opinion. In a multilingual classroom, 17% of pupils expressed some reluctance. Furthermore, 13% of pre-service biology teachers selected “Strongly disagree”, demonstrating their total unpreparedness to teach biology, even with some use of the English language, despite being familiar with teaching strategies.

In summary, it can be noted that pre-service biology teachers, from a methodological standpoint and in terms of their methodological competence, have a range of strategies, methods, and approaches for teaching biology, including CLIL-based ones. However, their limited English proficiency restricts their ability to fully harness their potential as educators.

Section 4: Psychological-Pedagogical Competence included two statements:

1. I know how to create a motivating classroom environment in a CLIL biology setting.

2. I am able to manage a bilingual classroom effectively while teaching complex biological topics.

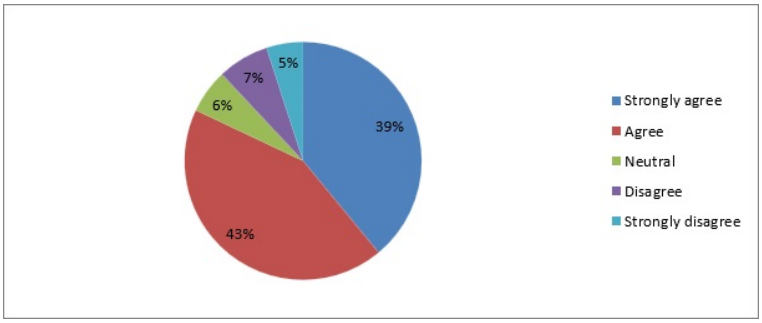


Fig. 7 *I know how to create a motivating classroom environment in a CLIL biology setting*

The Likert scale for measuring the Psychological-Pedagogical Competence of pre-service biology teachers within the framework of CLIL can encompass various areas of expertise. It combines psychological and educational knowledge and skills that teachers need to effectively support students' learning and development. This competence allows teachers to understand the psychological and pedagogical processes involved in learning and apply appropriate pedagogical strategies to foster students' academic, social, and emotional growth in multilingual education.

For the statement "I know how to create a motivating classroom environment in a CLIL biology setting", we obtained the following data. 39% of pre-school biology teachers confirmed their readiness to use various teaching tools to motivate students. Additionally, 43% of students also responded positively, which was the highest indicator, showing that a significant number of pre-school biology teachers understand how to enhance student motivation. 6% responded neutrally. 7% disagreed, and 5% strongly agreed, indicating that only a small percentage of respondents are either uncertain or unaware of the instructional strategies needed to increase students' interest in learning biology.

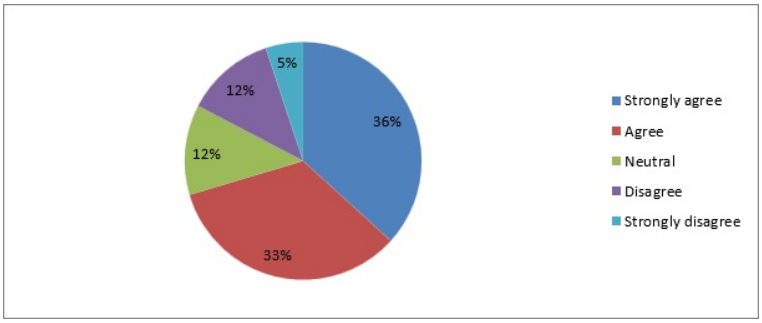


Fig. 8 *I can adapt teaching methods to the diverse psychological needs of students in a CLIL setting*

The statement "I can adapt teaching methods to the diverse psychological needs of students in a CLIL setting" yielded the following results. A total of 36% of students chose "Strongly agree," indicating that future educators believe they are ready and able to modify instructional strategies and technological tools to provide a differentiated approach that caters to different student kinds, levels, and skills. A further 33% gave the "Agree" response, indicating optimism. Another 12% said they are not prepared to modify teaching strategies for kids in a CLIL setting, and 12% adopted a neutral position. Lastly, 5% "strongly disagreed."

Despite including CLIL courses in the curriculum for third and fourth-year students, several obstacles remain, according to a survey on the development of professional competences in pre-service biology teachers. This mainly concerns biology students' Communicative Competence, especially their English proficiency, which is insufficient for teaching biology courses in English and remains poor in some groups. In addition to having trouble defining scientific vocabulary and concepts, students also have trouble participating in and sustaining scientific conversations in general.

The prospects for improving students' Methodological Competence are far more promising. Students exhibit competence and the capacity to use a variety of approaches, strategies, and tools when teaching biology in general and the CLIL approach in particular.

The results on enhancing psychological-pedagogical competence were also excellent. When using the CLIL approach, students are knowledgeable about motivating techniques, know how to increase motivation, and comprehend the proper ways to create a positive psychological atmosphere in the classroom while lowering stress.

In order to improve the first results, we started the experimental training over the course of the following year after gathering preliminary data on the professional competencies of future biology teachers. To achieve this, we employed various teaching methods, including discussion, heuristic approaches, inquiry-based learning, and problem-solving techniques. The use of these methods not only improved students' English

language proficiency by focusing on their communicative abilities but also fostered a deeper understanding of the subject matter in biology and its application in their professional activities.

After the experimental training, which lasted for a year, we moved on to the post-experimental phase, aimed at determining what changes occurred in the development of professional competencies. In the post-experimental phase, we utilized Meltze's Gain Index Classification.

The data for competency calculation are processed in the form of scores and interpreted according to the levels specified in the assessment rubric (excellent, competent, partially competent, needs improvement). The value processing is carried out as follows:

Value = $\frac{(TotalScore)}{(MaximumTotalScore)}$ ×100

Table I
Pedagogical value conversion

Average	Score	Competence Level
3,6-4	90-100	Excellent
2,6-3,5	75-89	Competent
2-2,5	50-74	Partially Competent
1-1,9	25-49	Needs Improvement

Competence improvement is also assessed through gain calculations. The formula applied is as follows:

Gain = $\frac{scoreposttest-scorepretest}{scoremaximum-scorepretest}$

The results of the gain calculation are interpreted using the gain index <g> according to the Meltzer (2002) classification are as follows:

g ≥ 0.7: High – Indicates a high level of improvement.

0.3 ≤ g < 0.7: Moderate – Indicates a moderate level of improvement.

g < 0.3: Low – Indicates a low level of improvement.

Analyzing the data collected according to Meltze's Gain Index Classification before -, during -, and after - the experiment, we obtained the following results.

Table II
Enhancing communicative competence

Communicative Competence	Pre-Test		During-Test		Post-Test	
	Value	Level	Value	Level	Value	Level
Meta-Language	44.79	Needs Improvement	56.46	Partially competent	75.12	Competent
Reading	66.67	Partially competent	73.71	Partially competent	85.64	Competent
Listening	54.86	Partially competent	64.89	Partially competent	77.22	Competent
Speaking	41.23	Needs Improvement	53.32	Partially competent	68.26	Partially competent
Writing	42.67	Needs Improvement	54.51	Partially competent	68.93	Partially competent
Average	50.04		60.57		75.04	

The post-experiment results showed clear improvements in communicative competence compared with the pre-experiment and during-experiment results. Overall, the average score rose to 75.04, indicating a competent level, up from 50.04, which indicated a need for improvement. This indicator reflected improvements across all skills, including reading, listening, speaking, and writing, as well as notable gains in the ability to use meta-language, particularly in mastering biological terminology and concepts. Thus, the average results in communicative competence changed from "Partially Competent" to "Competent".

Table III
Enhancing communicative competence

Communicative Competence	Score Preliminary	Score Final	Gain	Criteria
Meta-Language	44.79	75.12	0.54	Moderate
Reading	66.67	85.64	0.56	Moderate
Listening	54.86	77.22	0.49	Moderate
Speaking	41.23	68.26	0.46	Moderate
Writing	42.67	68.93	0,45	Moderate

Table III shows the gain calculation of pre-service biology teachers' communicative competence. According to the obtained data, the increase to the "Moderate" criteria affected all types of speech skills and meta-language.

Table IV
Enhancing methodological competence

Methodological Competence	Pre-Test		During-Test		Post-Test	
	Value	Level	Value	Level	Value	Level
Skills to Design Effective Lesson Plans	63.76	Partially Competent	75.18	Competent	84.72	Competent
Skills to Use of Educational Technologies	67.88	Partially competent	75.74	Competent	86.38	Competent
Skills in Utilizing various Assessment Tools	65.81	Partially competent	74.26	Partially competent	83.75	Competent
Average	65.82		75.06		85	

According to the data collected before, during, and after the experiment on developing methodological competence, the results were notably high. These data included various skills of the pre-service biology teachers, namely: Skills to design various types of lesson plans, both for traditional biology lessons and lessons using the CLIL approach; proficiency in modern methods and technologies for teaching biology as well as the ability to assess student responses, create test assignments, and develop assessment rubrics.

At the pre-test stage, the students' level was 65.82. During the experimental training, this figure rose to 75.06, and by the post-experiment stage, it reached 85. Thus, we can conclude that the competence level increased from 'Partially Competent' to 'Competent', which greatly pleased us as instructors.

Table V
Enhancing methodological competence

Methodological Competence	Score Preliminary	Score Final	Gain	Criteria
Skills to Design Effective Lesson Plans	63.76	84.72	0.57	Moderate
Skills to Use of Educational Technologies	67.88	86.38	0.57	Moderate
Skills in Utilizing various Assessment	65.81	83.75	0.52	Moderate

According to the obtained data shown in Table 5 regarding the development of Methodological Competence of pre-service biology teachers, it can also be concluded that gain was more than 0.5, and this, in turn, is the level of "Moderate".

Table VI
Enhancing psychological-pedagogical competence

Psychological-Pedagogical	Pre-Test		During-Test		Post-Test	
	Value	Level	Value	Level	Value	Level
Skills to establish a supportive and motivating classroom atmosphere	73.54	Partially Competent	79.21	Competent	87.53	Competent
Ability for classroom management	68.76	Partially competent	77.65	Competent	82.32	Competent
Skills in understanding learning styles, and individual differences of students	62.47	Partially competent	71.53	Partially competent	75.69	Competent
Average	68.25		76.13		81.84	

The analysis of data on the development of psychological-pedagogical competence in pre-service biology teachers within the CLIL framework revealed the inclusion of skills such as: Creating a positive classroom atmosphere, managing the class effectively, understanding various student learning styles, and applying a differentiated approach in biology teaching. The pre-experiment average result of 68.25 indicated a solid foundation that students had developed by the third year of the bachelor's program. However, during the experimental training and post-experiment phase, this figure rose significantly to 81.84. Thus, similar to the development of Methodological Competence, Psychological-Pedagogical Competence progressed from a "Partially Competent" level to a "Competent" one.

Table VII
Enhancing psychological-pedagogical competence

Psychological-Pedagogical Competence	Score Preliminary	Score Final	Gain	Criteria
Skills to establish a supportive and motivating classroom atmosphere	73.54	87.53	0.53	Moderate
Ability for classroom management	68.76	82.32	0.43	Moderate
Skills in understanding learning styles, and individual differences of students	62.47	75.69	0.35	Moderate

According to Table VII, the gain at the Moderate level also affected two criteria of Psychological-Pedagogical Competence of pre-service

biology teachers, namely: skills to establish a supportive and motivating classroom atmosphere and the ability for classroom management. The criterion 'skills in understanding learning styles and individual differences of students' also showed a moderate gain of 0.35.

Table VIII
Enhancing subject-specific competence

Subject-Specific Competence	Pre-Test		During-Test		Post-Test	
	Value	Level	Value	Level	Value	Level
Content Knowledge	62.31	Partially Competent	69.22	Partially Competent	77.57	Competent
Curricular Knowledge	68.64	Partially competent	73.67	Partially Competent	80.34	Competent
Pedagogical Content Knowledge (PCK)	63.27	Partially competent	71.54	Partially competent	75.51	Competent
Average	64.74		71.47		77.80	

Throughout the pre-experimental, during-experimental, and post-experimental tests focused on developing Subject Competence, the following outcomes were obtained. For the "Content Knowledge" criterion, students achieved 62.31 in the pre-experimental phase, 69.22 during the experimental training, and 77.57 in the post-experimental phase. For the "Curricular Knowledge" criterion, students' performance was rated 68.64 at the pre-test stage, 73.67 during the test, and 80.34 in the post-experimental stage. The "Pedagogical Content Knowledge (PCK)" criterion also rose from 63.27 in the pre-experimental phase to 71.54 during the intermediate phase and 75.51 in the post-experimental phase. In summary, the average students' scores were 64.74 in the pre-experiment, increased to 71.47 during the experiment, and further improved to 77.80 in the post-test. Although the results demonstrated improvement across all criteria, the changes were relatively modest.

Table IX
Enhancing subject-specific competence

Subject-Specific Competence	Score Preliminary	Score Final	Gain	Criteria
Content Knowledge	62.31	77.57	0.40	Moderate
Curricular Knowledge	68.64	80.34	0.37	Moderate
Pedagogical Content Knowledge (PCK)	63.27	75.51	0.33	Moderate

Table IX reflects improvements in subject-specific competence; the gains for the 'Curricular Knowledge' and 'Pedagogical Content Knowledge (PCK)' criteria were moderate, with values of 0.37 and 0.33, respectively. As for the Content Knowledge criterion, it has changed to the Moderate level.

In summary, professional competencies improved in communicative, methodological, and, to some extent, psychological-pedagogical competence. However, the increase in subject competence was low.

The more limited improvement in subject-specific competence may be explained by the fact that CLIL-based training simultaneously requires students to process biological content and use a foreign language for learning and teaching. Although the CLIL approach offered significant potential for the development of methodological and communicative skills, longer and more extensive subject-focused learning may be necessary for the acquisition of deeper subject-specific knowledge. This may be particularly relevant for complex biological concepts, where students need sufficient time to consolidate scientific knowledge in addition to developing the language required to communicate it.

These findings are broadly consistent with previous research emphasizing the integrated nature of CLIL and the importance of combining content and language development. Pittas and Tompkins (2024) and H. Hu et al. (2023) emphasize that CLIL requires the simultaneous development of content, communication, cognition, and culture, while Dalton-Puffer (2008) highlights the role of language in supporting subject learning. The present findings extend this perspective by showing that CLIL-based training can contribute to several dimensions of pre-service teachers' professional competence, although the extent of improvement may differ across competency areas. The stronger gains observed in communicative and methodological competence suggest that these areas may respond more directly to the language-integrated and practice-oriented nature of CLIL training, whereas subject-specific competence may require additional subject-focused intervention.

Conclusion

The findings of this study suggest that the integration of Content and Language Integrated Learning (CLIL) into the training of pre-service biology teachers can contribute to the development of professional competences across four essential domains: Subject-Specific, Communicative, Methodological, and Psychological-Pedagogical. In addition to enhancing biology instructors' subject-matter competence, this multimodal approach equips them with the essential skills and competencies to effectively teach in diverse, multilingual classroom settings. As a result, CLIL promotes the growth of more adaptable and dynamic teachers who are prepared to meet the shifting needs of modern education.

We were able to determine the primary professional competencies of pre-service biology teachers through a thorough and in-depth assessment of the literature.

The foundation of a teacher's professional identity is Subject-Specific Competence, which CLIL strengthens by encouraging a deeper connection with biological subject. When teaching biology using CLIL, instructors must explain complex scientific ideas in a way that students who may not be fluent in the language of instruction can comprehend. Pre-service instructors must simplify and rewrite difficult information without sacrificing the content's accuracy, which necessitates a deeper understanding of biology. By encouraging this skill, CLIL helps pre-service teachers improve their subject-specific expertise and become more adaptable when presenting biological material to a variety of students.

Another crucial professional growth skill that CLIL supports is communicative competence. Pre-service biology instructors should be adept in both the language of instruction and a range of communication techniques in a CLIL situation. By encouraging teachers to engage students through a variety of communication channels and go beyond verbal explanations, CLIL promotes more effective and clear instruction. Additionally, by emphasizing communicative skills, pre-service biology instructors are better equipped to identify and meet the needs of students with varying language proficiency levels, creating an inclusive learning environment.

Because CLIL encourages teachers to implement innovative teaching practices that integrate language and topic learning, it also significantly improves methodological competence. Pre-service biology instructors are encouraged by CLIL to use interactive learning strategies, such as inquiry-based learning, project-based learning, and cooperative group work. In order to foster a more dynamic and interesting learning environment, pre-service teachers must develop their ability to design lessons that integrate language and topic objectives. In today's classrooms, where customized instruction is often needed to attain individual learning objectives, this methodological flexibility is essential for meeting the diverse requirements of students.

Another important skill that can be developed through CLIL is psychological-pedagogical competence. The cognitive and emotional needs of their students should be taken into account by pre-service biology teachers. There are many obstacles when teaching biology in a foreign language; therefore, it's critical for educators to establish encouraging, supportive environments where students feel free to take chances and make mistakes. By encouraging techniques that reduce fear and increase confidence, CLIL helps pre-service teachers gain empathy and understanding for the difficulties that students encounter. Additionally, CLIL encourages the use of a learner-centered approach, in which pre-service teachers are taught to take into account each student's unique learning style and pace. They are able to create inclusive and adaptable teaching methods that support each student's holistic development because of this psychological-pedagogical insight.

The results indicate that pre-service biology teachers can acquire professional competencies in subject-specific, communicative, methodological, and psychological-pedagogical domains by integrating CLIL into their training. This all-encompassing method equips aspiring teachers with the information, abilities, and tactics needed to successfully negotiate the challenges of modern education, especially in multilingual and multicultural classroom settings.

The study has a number of limitations that should be noted. A single cohort of pre-service biology teachers participated in the study, which was carried out at a single institution without a control group. As a result, the results should not be applied to all pre-service biology teachers or educational settings, and the observed changes cannot be solely ascribed to the CLIL intervention. Furthermore, the study excluded inferential statistical tests and mostly relied on descriptive analysis.

To better demonstrate the benefits of CLIL-based teacher training, future studies should include control or comparison groups and bigger, more varied samples from several institutions. To ascertain whether the noted changes are sustainable, future research might also use inferential statistical techniques and look at how professional competences evolve over longer time periods.

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