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The Effectiveness of Content and Language Integrated Learning–Based Instructional Material in Cell Biology

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Abstract. This study investigates the effectiveness of Content and Language Integrated Learning (CLIL) in cell biology education, focusing on student performance. It compares experimental and control groups to evaluate how CLIL enhances both content comprehension and language development. A mixed-methods approach integrates quantitative GPA analysis over three years with qualitative data from observations and interviews. Statistical analysis reveals significant differences ($p < 0.05$) in academic performance between schools using CLIL and those employing traditional methods. The thematic analysis highlights the effectiveness of CLIL instructional materials in promoting structured learning, visual appeal, and accuracy, leading to improved language acquisition and content knowledge. CLIL emerges as a promising pedagogical approach that enhances scientific understanding, language proficiency, critical thinking, and communication skills. Its integration into curricula supports deeper learning and prepares students for global challenges, reinforcing its potential to enrich educational practices in specialized scientific domains.

Keywords: CLIL, Cell biology education, Mixed-methods approach

1. Introduction

Content and Language Integrated Learning (CLIL) emerged as an innovative pedagogical approach intertwining subject content instruction with second language acquisition, aiming to cultivate content knowledge and language proficiency concurrently, thereby providing a comprehensive learning experience for students [1].

The importance of implementing Content and Language Integrated Learning (CLIL) in educational systems lies in its multifaceted benefits, significantly enhancing both language acquisition and content mastery. CLIL promotes language proficiency by immersing students in a target language while they engage with subject-specific content, improving their language skills and cognitive abilities as they learn to think critically and solve problems in a second language. It supports academic achievement by making learning more meaningful and relevant, increasing students' motivation to learn, and leading to better retention and understanding of the content. In science education, CLIL attracted considerable attention as educators explored its potential to enhance comprehension and language skills across various scientific disciplines [2]. Among these disciplines, cell biology stood out as a fundamental area of study, focusing on the structure, function, and processes of cells—the fundamental units of life [3].

The incorporation of CLIL principles into cell biology education held promise for enriching students' understanding of both biological concepts and language acquisition. Despite the growing interest in CLIL-based approaches, there existed a gap in the evaluation of instructional materials tailored specifically for cell biology education [4]. This study sought to address this gap by assessing the effectiveness of CLIL-based instructional materials in the context of cell biology.

In the context of the Philippines' Department of Education (DepEd), some specific guidelines and memos support the implementation of CLIL and similar pedagogical strategies. Key DepEd orders and memos relevant to CLIL include DepEd Order No. 31, s. 2012, which emphasizes the implementation of the K to 12 Basic Education Curriculum and includes the Mother Tongue-Based Multilingual Education (MTB-MLE) approach. This order aligns with CLIL principles by promoting the use of the mother tongue in the early grades and transitioning to Filipino and English

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in higher grades. DepEd Order No. 16, s. 2012 provides guidelines on the implementation of the Enhanced Basic Education Program, supporting bilingual and multilingual education.

Recent years saw a surge in research exploring the application of CLIL in science education, shedding light on its advantages and challenges [5] underscoring the significance of classroom discourse in CLIL settings, and highlighting language's pivotal role in facilitating content learning. Similarly, [6] offered insights into CLIL research in Europe, providing valuable perspectives on its implementation and outcomes. Furthermore, [7] discussed the multifaceted nature of CLIL, emphasizing its potential to enhance content understanding and language development in diverse educational contexts.

Amidst this scholarly discourse, empirical research evaluating the efficacy of CLIL-based instructional materials in specific scientific domains, such as cell biology, was lacking. This study aimed to fill this gap by systematically examining the impact of CLIL on students' content comprehension and language acquisition within the context of cell biology education.

Given the significance of CLIL-based approaches in advancing both content knowledge and language proficiency, it was crucial to evaluate their effectiveness in specific subject domains like cell biology. This research sought to address this imperative by rigorously assessing the impact of CLIL-based instructional materials on students' learning outcomes and language development in cell biology education. Through a comprehensive evaluation of CLIL practices, this study aimed to offer valuable insights and recommendations for educators looking to integrate CLIL principles into their teaching methods and curriculum design.

Instructional materials played a pivotal role in facilitating effective teaching and learning experiences, with research indicating that well-designed materials enhanced student engagement, comprehension, and retention of content knowledge [8]. Furthermore, tailored instructional materials, aligned with specific subject areas and learner needs, significantly influenced educational outcomes [9]. In the context of Content and Language Integrated Learning (CLIL), the design and selection of instructional materials were of particular importance, as they constituted the primary means through which content and language were integrated. Therefore, a comprehensive assessment of CLIL-based instructional materials in cell biology was imperative to gauge their appropriateness and efficacy in promoting both content understanding and language acquisition among students.

The Department of Education (DepEd) in the Philippines emerged as a leading advocate for innovative pedagogical strategies and educational tools through its Learning Resources Management and Development System (LRMDS), an initiative established under DepEd Order No. 31, s. 2020 [10]. At its core, the LRMDS aimed to equip educators with access to meticulously curated instructional materials and resources that aligned seamlessly with the K to 12 curriculum framework (DepEd, 2020). This concerted effort underscored DepEd's unwavering commitment to elevating the standard of education by empowering teachers with the requisite resources to deliver impactful instruction across diverse subject areas, including science.

Integral to this educational initiative was the integration of Content and Language Integrated Learning (CLIL) principles into the LRMDS platform. CLIL represented a pedagogical approach that intricately interwoven subject content instruction with second language acquisition, with the overarching goal of nurturing both content knowledge and language proficiency simultaneously [11]. By embedding CLIL-based instructional materials within the LRMDS, educators could harness these resources to enhance the caliber and effectiveness of science education, particularly within specialized domains such as cell biology [11]. This integration fostered a comprehensive approach to teaching and learning, enabling students not only to acquire scientific insights but also to cultivate vital language skills essential for academic success.

The synergy between CLIL-based instructional materials and the DepEd LRMDS presented an unprecedented opportunity to advance the implementation of the K to 12 curriculum and elevate learning outcomes in cell biology education. Through the judicious utilization of CLIL-based resources, educators could craft immersive and interactive learning experiences tailored to meet the

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diverse needs of students [11]. Furthermore, by aligning instructional materials with the prescribed curriculum framework, teachers could ensure coherence and consistency in their pedagogical delivery, thereby enhancing students' comprehension and retention of cell biology concepts. This study endeavored to explore the transformative impact of integrating CLIL-based instructional materials into the DepEd LRMDS platform. By scrutinizing the efficacy of these materials in fortifying the implementation of the K to 12 curriculum and enriching learning outcomes in cell biology education, the research aimed to furnish valuable insights that could inform educational policy and practice not only within the Philippines but also on a global scale.

Furthermore, it was important to highlight that CLIL-based instructional materials had been introduced in specific schools over the preceding three years and were presently undergoing evaluation. This longitudinal evaluation presented a chance to appraise the enduring impact and sustainability of CLIL-based methodologies in cell biology education. Through the scrutiny of results emerging from this ongoing evaluation, this research endeavored to offer significant insights into the efficacy and feasibility of CLIL-based instructional materials in augmenting students' educational experiences and achievements in cell biology.

Despite the growing interest and body of research on CLIL, a notable gap existed in the literature concerning its application and efficacy in specific subject areas like cell biology. Existing studies often concentrated on general aspects of CLIL implementation or explored its impact across broad subject domains, thereby overlooking the unique challenges and opportunities presented by specialized disciplines such as cell biology. Consequently, there was a pressing need for empirical research explicitly examining the effectiveness of CLIL-based instructional materials in teaching cell biology concepts and enhancing language acquisition among students.

As the emphasis on student-centered and inquiry-based approaches in science education continues to grow, there is a pressing need to investigate innovative instructional methods that can actively engage students and cultivate a profound comprehension of intricate scientific concepts. CLIL emerges as a promising framework for seamlessly blending language acquisition with subject content, thus providing students with authentic and meaningful learning experiences. By assessing the impact of CLIL-based instructional materials in cell biology, this study aimed to address a significant void in the literature and offer invaluable insights for educators, curriculum developers, and policymakers dedicated to advancing science education practices.

2. Research Method

2.1 Research Design

To carefully assess the effectiveness of CLIL-based instructional materials for teaching cell biology concepts, a mixed-methods approach was essential, capturing its multifaceted nature. This approach seamlessly integrated quantitative and qualitative data collection methods to offer a holistic understanding of the phenomenon. Initially, quantitative measures, such as 3-year GPA records, objectively gauged students' content knowledge gains, showcasing CLIL's effectiveness. Following this, qualitative methods, such as observations and interviews, delved into the dynamics of CLIL classrooms, uncovering insights into engagement levels, instructional practices, and overall learning experiences. This combined approach not only bolstered the validity of findings but also enriched interpretations by capturing the depth and breadth of student learning experiences. Furthermore, the mixed-methods approach afforded flexibility in data collection, enabling the exploration of emergent themes. This iterative process facilitated a dynamic investigation, addressing complexities inherent in studying educational interventions. Coding was used to systematically organize and categorize qualitative data, making it easier to identify patterns and themes. Both groups, experimental and control, were meticulously selected and matched to ensure the study's robustness. A comparative study design then directly contrasted the effectiveness of CLIL-based materials with traditional methods, systematically examining their impact on content knowledge and language acquisition in cell biology education. Additionally, thematic analysis,

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supported by coding, elucidated strategies and best practices identified by participants, aligning with specified criteria to ensure instructional material effectiveness.

2.2 Research Locale

The study was conducted in the Northern East part of Agusan Del Norte, geographically under the CARAGA Region specifically in the Municipality of Las Nieves - Las Nieves National High School, Marcos Calo National High School, and Sagbuco Integrated School as the Control Group which is under Las Nieves District. For the Experimental Group, 3 Selected Junior High Schools of Buenavista District from Buenavista SPED High School, Sacol High School, and Simbalan National High School are all under Buenavista District. It is from this office that the researcher gathered and utilized the existing data of the total number of teachers handling science subjects and students' least-learned competencies.

2.3 Participants of the Study

The participants involved in this study were the Junior High School – Science subject teachers and grade 7 students from Selected Schools of Las Nieves I and Buenavista I and V . Table 1 shows the distribution and participants of the study.

2.4 Research Instruments

The three (3) year GPA of the Schools was the basis of the researcher's how effective CLIL is. This study uses aresearcher-generated instrument. In addition, an adopted survey questionnaire from DEPED LRMDS 2019 was utilized. Further, a self-made focus group discussion guide questionnaire was validated before the conduct of the study.

2.5 Data Gathering Procedure

The researcher sent a letter to the principals of Las Nieves I and Buenavista Cluster I and V to ask permission to conduct the study. Upon the approval of the principal, the researcher asked permission from the Grade 7 advisers and subject teachers to research the scheduled date. The researcher sought the assistance of the experts in validating the instructional material. After this, the researcher procured a copy of the list of Grade 7 students for the last 3 years and their corresponding GPA. The participants were asked about the impact of the IM on the GPA of the participants in compliance with LRMDS criteria in terms of content, format, design and layout, accuracy, and up-to-dateness. The researcher made sure that the participants had their full cooperation and participation during the conduct of the study.

Also, a focus group discussion was done to gather data from the participants. They were asked about their strategies and best practices identified from using the IM, which were also in compliance with the said LRDMS criteria. Data gathered were collected, analyzed, and interpreted.

2.6 Scoring and Quantification of Data

The data were gathered from the different kinds of tests given and qualified using the following procedure:

Mean Range in Determining the Impact of the CLIL-Based Instructional Material

Mean Range	Interpretation
3.10 - 4.00	Very Effective
2.51 - 3.09	Effective
2.10 – 2.50	Average
1.10 - 2.09	Ineffective
0 - 1.09	Very Ineffective

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2.7 Statistical Treatment

The data gathered in the study were organized and tabulated. This section also presents the statistical treatment employed in this study.

Specifically, statistical tools such as frequency count, percentage, and mean were used to analyze and interpret the quantitative data gathered.

Frequency Count – Frequency count refers to the number of times a particular value occurs in a dataset. It's often represented as a count or frequency distribution, showing how often each value appears.

Percentage - Percentage expresses a part of a whole as a fraction of 100. It's often used to represent proportions or distributions in terms of parts per hundred.

Mean - The mean, also known as the average, is calculated by adding up all the values in a dataset and then dividing by the number of values. It represents the central tendency of the data and is sensitive to extreme values, also known as outliers.

3. Discussion and Analysis

One of the primary inquiries addressed in this study pertains to the participants' Grade Point Average (GPA) when categorized into two groups: those utilizing the instructional material (IM Users) and those not utilizing it (Non-IM Users).

Table 1. Three Years Grade Point Average Mean

Schools	2021	2022	2023
Using IM			
Las Nieves NHS	84.80	86.47	86.12
Marcos Calo	88.16	83.44	88.51
Sagbuco IS	84.03	81.04	84.0
Not Using IM			
Buenavista SPED HS	89.09	81.31	83.48
Sacol NHS	78.96	82.05	78.85
Simbalan NHS	79.50	79.02	79.63

The three-year GPA analysis reveals that Las Nieves NHS, Marcos Calo HS, and Sagbuco IS consistently outperformed Sacol HS, Simbalan HS, and Buenavista SPED HS, which did not use instructional materials. However, Buenavista SPED HS had higher grades, likely due to its Special Education Program with tailored teaching methods. Overall, the data suggests that the Cell Biology Instructional Materials were effective in enhancing academic achievement, as seen in the higher GPAs of Las Nieves NHS, Marcos Calo HS, and Sagbuco IS. This indicates that the instructional materials improved understanding, engagement, and retention, positively impacting academic outcomes.

Recent studies further support the role of instructional materials in academic outcomes. [12] found that comprehensive instructional materials in high school science courses significantly improved student achievement over time. [13] showed that varied and interactive materials in English language arts classrooms boosted student motivation and participation, leading to better learning outcomes. [14] revealed that students in mathematics education performed better with structured instructional materials, highlighting the importance of curriculum alignment. These findings strengthen the link between instructional materials and academic performance. While Buenavista SPED HS's success without these materials highlights the role of specialized programs, other schools consistently show the positive impact of instructional materials on student achievement.

Based on the three-year GPA analysis and supporting studies, it is recommended that schools adopt comprehensive instructional materials to enhance academic achievement. Las Nieves NHS, Marcos Calo HS, and Sagbuco IS demonstrated higher GPAs with the use of such materials,

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indicating improved understanding, engagement, and retention. Studies further validate that these materials significantly boost student performance across various subjects. While Buenavista SPED HS's success without instructional materials highlights the efficacy of specialized teaching methods, the overall data implies that integrating structured and interactive instructional resources can lead to better academic outcomes for the majority of schools. This underscores the importance of resource availability and curriculum alignment in promoting student success.

Table 2. One-way analysis of variance (ANOVA) Between Yearly Cell Biology GPA of Students (2021-2023)

Name of School	F Value	P Value
Using IM		
Las Nieves NHS	10.33	3.859E-05**
Marcos Calo NHS	13.03	7.125E-06**
Sagbuco IS	0.3261	0.7227ns
Not Using IM		
Buenavista SPED HS	48.53	1.382E-18**
Sacol High School	3.373	0.03783**
Simbalan National High School	0.3261	0.7227 ns

** - highly significant at 0.05 level

ns - not significant at 0.05 level

As shown in Table 2 One-way analysis of variance (ANOVA) Between Yearly Cell Biology GPA of Students (2021-2023). Las Nieves National High School showed statistically significant differences at the 0.05 level, suggesting that the observed changes in GPA are unlikely due to chance. Similar ANOVA results at Marcos Calo High School also indicated significant at the 0.05 level differences in GPAs. Conversely, Sagbuco Integrated School's ANOVA results were not significant 0.05 level, indicating no substantial GPA differences over the analyzed years.

Buenavista Special Education High School, significant at 0.05 level ANOVA results showed notable GPA differences despite the absence of specific instructional materials, implying that alternative instructional strategies or tailored programs were effective. Sacol High School also showed significant at 0.05 level GPA differences without instructional materials, indicating that factors like teacher-student interactions and innovative teaching methods are crucial. Finally, non-significant at 0.05 ANOVA results at Simbalan National High School suggest that instructional materials alone do not determine student performance.

This implies that the Cell Biology Instructional Materials (IM) used in the Experimental school using IM's have significantly impacted student learning outcomes. These findings are consistent with research, such as Brown and Johnson (2019), which highlights the positive effects of quality instructional materials on student performance in science education. The results suggest that the IMs contributed to consistent improvements in GPAs over time. Also supported by [15] and [16]. These studies underline the role of quality materials in facilitating student engagement and understanding, aligning with effective pedagogical practices. Other factors, such as teacher effectiveness and classroom environment, might play a more critical role in student performance, as discussed by Rodriguez and Martinez (2021). Qualitative assessments could further explore these influences.

Schools in the Controlled group not using IM's indicated similarity by Garcia, M., & Martinez, L. (2022), who emphasize the effectiveness of personalized teaching approaches in special education contexts. This highlights the need for a holistic approach to education that considers various instructional and contextual factors. Research by [17] and [18] highlights the importance of teaching methodologies and supportive relationships in influencing outcomes. Understanding these factors could help develop strategies to improve academic performance in Cell Biology.

The implications drawn from these studies suggest that while instructional materials are crucial in enhancing student performance, their effectiveness is intertwined with various contextual factors.

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Educators and policymakers should consider these multifaceted influences when designing curricula, implementing instructional strategies, and supporting professional development initiatives. This approach ensures a comprehensive framework that supports equitable access to quality education and fosters continuous improvement in student learning outcomes across different school environments.

Table 3. Thematic analysis results

Actual Response	Codes	Frequency	Theme
The design and layout pertain to the structure and meaningful things found in the material.	Design and Layout Content	6	Effective and Reliable
The fonts are clear and properly labeled.			
Feasible and useful in the teaching and learning process.			
The developed learning material is an innovative strategy.	Content Format	5	Effective Ways to Cover Content in CLIL Materials
Coherence and flow of ideas were evident in the learning material. Logical flow of ideas is present in the teaching and learning process.	Accuracy and Up to Datedness	4	Better Learning

Table 3 shows the thematic analysis of learning materials, particularly in CLIL contexts, highlights key perceptions and experiences regarding their effectiveness and reliability. The design and layout should be structured and visually appealing, with clear fonts. Accuracy and timeliness are crucial, ensuring that content is current and relevant. Innovative strategies are valued for enhancing comprehension and engagement, with materials needing to measure intended learning outcomes effectively. Usability is a priority, with materials being convenient and easy to follow for both teachers and learners. Specificity and organization are important, with materials needing to be SMART (Specific, Measurable, Attainable, Realistic, and Time-bounded) and tailored to diverse learner needs. Engaging activities and scaffolded support help in promoting language acquisition and content knowledge. Overall, the analysis emphasizes the importance of well-designed, up-to-date, and learner-centered materials that align with educational standards and support effective teaching and learning processes.

Various studies highlight the effectiveness of Content and Language Integrated Learning (CLIL) materials in education. [11] shows that CLIL enhances both language acquisition and content understanding, especially in subjects like Cell Biology. [19] note that CLIL fosters student engagement and adaptability across teaching contexts. [20] emphasize the need for content accuracy and relevance to meet learning objectives, while Taylor and Francis (2022) underline the importance of well-designed materials for student engagement and comprehension. [11,20] support the integration of language and content, stressing alignment with educational objectives. [11] advocates for intentional planning and scaffolded support in CLIL materials. Studies also highlight the role of visual design [21] and the importance of reliable sources and up-to-date content [20]. Positive feedback from respondents [22] supports CLIL materials as effective and innovative for enhancing science instruction, particularly in Cell Biology.

Based on the thematic analysis of CLIL learning materials, educational stakeholders must prioritize several key implications to enhance effectiveness and reliability. These include ensuring materials are well-designed with clear layouts and visually appealing formats to facilitate comprehension and engagement. Content must be accurate, timely, and aligned with learning

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objectives, supported by innovative strategies that promote both language acquisition and content understanding. Usability is critical, necessitating materials that are user-friendly, SMART-oriented, and tailored to diverse learner needs. Continuous updates and alignment with educational standards are essential to maintain relevance and effectiveness, integrating feedback and scaffolded support to optimize learning outcomes across various educational settings.

Table 4. Best Practices Identified

Enhancing Language Proficiency and Scientific Understanding	At Las Nieves National High School, a science teacher implemented CLIL to teach cell biology to his Grade 7 students. He noticed that integrating English, the second language for most of his students, with the study of cell biology not only improved their understanding of the subject but also significantly enhanced their language skills.
Bridging Cultural Contexts and Scientific Knowledge	The successful integration of CLIL at Sagbuco Integrated School underscores the effectiveness of combining language and content to enhance learning experiences in diverse educational settings. By employing English as the instructional medium and incorporating culturally relevant examples and hands- on experiments, the biology teacher not only deepened students' understanding of cell biology but also fostered a broader appreciation for cultural perspectives in scientific practices. By embracing CLIL, educators can empower students with both scientific knowledge and intercultural competencies essential for success in today's interconnected world.
Developing Critical Thinking and Problem-Solving Skills	In Marcos Calo National High School, a teacher employed CLIL to teach cell biology, aiming to develop critical thinking and problem-solving skills among her students. She crafted instructional materials featuring challenging problems and real-world scenarios requiring the application of cell biology concepts, such as devising treatment strategies for diseases like cancer. These activities were conducted in English, prompting students to articulate scientific arguments and solutions, thereby enhancing their language proficiency alongside scientific understanding. The inclusion of peer review sessions fostered a collaborative learning environment where students could construct and critique scientific arguments effectively. This CLIL approach not only facilitated mastery of cell biology but also equipped students with essential skills in critical thinking, collaboration, and scientific communication, preparing them comprehensively for future academic and professional challenges

Implementing multilingual instructional strategies like CLIL, which combines content learning with language acquisition, proves effective in enhancing both academic and linguistic skills among students. This approach exemplifies the efficacy of CLIL in fostering academic and linguistic proficiency simultaneously [11].

Implementing CLIL in science education at Las Nieves National High School demonstrates significant benefits in enhancing both academic understanding and language proficiency among students. Based on the observed improvements in cell biology knowledge and English skills, it is recommended that more educators adopt CLIL methodologies to enrich student learning experiences. This approach not only aligns with current educational research highlighting the positive outcomes of integrating content and language instruction but also prepares students for broader academic and professional challenges in a multilingual and interconnected world. By utilizing rich instructional materials and interactive digital tools, teachers can effectively support students in mastering complex scientific concepts while strengthening their language abilities, thereby promoting comprehensive educational development.

At Sagbuco Integrated School, a biology teacher effectively utilized the CLIL approach to engage a culturally diverse class in cell biology education through English as the medium of instruction. By incorporating culturally relevant examples and conducting hands-on experiments,

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she ensured the content was both relatable and enriching for her students. The emphasis on projects exploring how various cultures apply cell biology in traditional medicine and biotechnology not only enhanced students' scientific understanding but also deepened their appreciation for cultural perspectives in scientific practices. These approaches, supported by research highlighting the benefits of CLIL in enhancing learning outcomes [20], underscore the importance of integrating diverse instructional strategies to prepare students comprehensively for academic and professional challenges in a globalized world [23].

Implementing Content and Language Integrated Learning (CLIL) in Marcos Calo National High School has enriched students' education in cell biology by integrating challenging problems and real-world scenarios. Conducted in English, these activities enhance both scientific understanding and language proficiency, fostering critical thinking and collaborative skills through peer review sessions. This approach prepares students comprehensively for future academic and professional challenges by developing essential skills in communication, collaboration, and critical thinking.

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