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INTERVENTION OF CLIL APPROACH ON ACADEMIC LANGUAGE DEVELOPMENT IN SCIENCE AND MATHEMATICS

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ABSTRACT

Content and Language Integrated Learning (CLIL) is an instructional approach that simultaneously develops subject knowledge and language skills. In India, several government exams mandate the clearance of English and Hindi language papers as a compulsory component. Schools and Universities mainly focus on concept attainment rather than enhancing students' vocabulary or language proficiency, leading students to rely on rote memorization of scientific and mathematical terms. To mitigate this gap, an effort was made to introduce the CLIL approach towards instructing Science and Mathematics in both the target languages. This study aimed to bridge this gap by fostering collaboration between language and subject teachers to customize content integrating language development into Science and Mathematics instruction with a focus on the 4C's of CLIL pedagogy; content, communication, cognition and culture. The study involved a sample of 40 prospective teachers from the Department of Education, Chitkara University, Punjab, India, divided into an experimental group (20 participants receiving CLIL-based instruction) and a control group (20 participants receiving traditional instruction). The study adopted mixed-method approach. Quantitative analysis was carried out by employing t-test and Pearson's Correlation. The post-test scores of both groups revealed that experimental group (Science; Mean = 11.650 and Maths; Mean = 17.3) was doing better than the control group (Science; Mean = 9.950 and Maths; Mean = 13.8) in both disciplines but there was no significant relationship between the achievement of scores in Science and Mathematics. Qualitative data from interviews and classroom observations underwent thematic analysis which revealed the positive attitude of students and teachers towards CLIL pedagogy. However, they reported challenges like teacher expertise and training, balancing content and language instruction, resource availability and accessibility, time constraints and workload in its implementation.

Keywords: *Academic Language Development, CLIL, Science and Mathematics Education, Student Achievement, Teacher Collaboration*

Introduction

As global demands change, education must adapt. Developing effective teaching methods that integrate language learning with meaningful content is key to this shift. Content and Language Integrated Learning (CLIL) is a widely recognized pedagogy that enhances exposure to the target language while teaching subject content (Council of Europe, 2019). In the past decade, both European and non-European educational policies have increasingly emphasized the importance of learning a second language. As English is the global language of science and technology, it has become central to bilingual education policies, with CLIL being a key pedagogical model (Ruiz-Cecilia et al., 2023). CLIL supports multilingualism, particularly by integrating various vehicular and vernacular languages. One of the key conceptual models in CLIL was proposed by Coyle (2005). His model includes four components: 1) content (topics taught in a second language); 2) communication (verbal, non-verbal, and multimodal interactions); 3) culture (the role of cultural context in learning), and iv) cognition (enhancing higher-order thinking through problem-solving). Over the past two decades, the growing recognition of the benefits of teaching content in a second language (L2) has led to widespread adoption of this approach, which enhances both subject knowledge and L2 proficiency (Dalton-Puffer, 2007; Surmont et al., 2016). Wolff (2005) highlights CLIL's role in developing reading skills, not only for comprehension but also for presenting content and supporting other language abilities. As a result, many education systems globally have adopted CLIL to teach foreign languages and promote multilingualism (Luanganggoon, 2020; Keeratisuntorn & Sukavatee, 2023). In conclusion, CLIL is a recognized approach that integrates subject-matter instruction with second language learning. With English as the global language of science and technology, CLIL has become central to bilingual education policies worldwide. This paper explores the effectiveness of CLIL in promoting higher-order thinking and multilingualism in Science and Mathematics education.

Literature Review

CLIL, especially when combined with technology and interactive methods like debates, improves comprehension, participation and language learning (Coyle et al., 2010). As a multilingual and intercultural approach, it is ideal for diverse classrooms, promoting inclusion, motivation and key competencies (Schietroma, 2019). Its flexibility makes it effective in addressing challenges in multicultural education (Coyle, 2007). CLIL is a growing force in multilingual and intercultural education, promoting critical thinking through deeper cognitive engagement (Cinganotto, 2023). While CLIL positively impacts language acquisition and subject understanding, its successful implementation faces challenges, including the need for more teacher support and clear learning goals (Asdarina et al., 2024). Successful CLIL implementation requires strategies that focus on teacher support and clear, student-centred objectives. CLIL boosts both intrinsic motivations, like enjoyment and extrinsic motivation, such as increased self-confidence and lower anxiety

(Martí et al., 2022; Roth et al. (2022) found modular CLIL teaching helps low-achieving students, though the dual challenge of content and language can cause exhaustion. Macaraeg et al. (2024) emphasizes the need for targeted vocabulary development and teacher training. Ruiz-Cecilia et al. (2023) found mixed results in Mathematics, while Tagnin et al. (2020) noted practical limitations in teaching CLIL in Math. Surmont et al. (2016) show that CLIL improves Math performance, while Tagnin and Riordain (2021) warn that oversimplifying language can reduce the depth of the subject. Coellar (2021) suggests that scaffolding, code-switching, and multilingual resources enhance both language and content learning. CLIL also boosts reading skills by providing subject-specific L2 vocabulary, improving comprehension (Hartiala, 2000). CLIL is a valuable multilingual and intercultural approach that promotes inclusion, motivation and key competencies. However, its limitations include the need for more teacher support, unclear learning goals, mental exhaustion, vocabulary challenges and the risk of oversimplification.

Need and Significance of the Study

In European schools, subjects are often taught in a second language (L2), aligning with the European Commission's White Paper (1995), which encourages learning topics in a first foreign language to promote multilingualism and cultural awareness. In India, English and Hindi proficiency is required for various government exams, yet students from private (English-medium) and government (Hindi-medium) schools often struggle due to limited academic exposure to both languages. To bridge this gap, this study introduced the CLIL approach for teaching Science and Mathematics in both English and Hindi. The paper examines the bilingual benefits of CLIL in improving language skills and subject understanding, while also exploring the attitudes of teachers and students towards CLIL implementation.

Theoretical Background of CLIL

Several key educational and linguistic theories support the foundation of Content and Language Integrated Learning (CLIL). Krashen's (1982) theory of implicit language acquisition highlights subconscious learning through meaningful content. Vygotsky (1978) stresses the role of social interaction and scaffolding, while Piaget's (1963) constructivist theory sees learning as building on prior knowledge. Cummins (1981) adds that language can be developed in both academic and social settings. Together, these theories support CLIL's dual-focus approach, emphasizing meaningful content, social learning and regional language context.

Objectives

1. To study the improvement in both content knowledge and language proficiency with the CLIL pedagogy intervention in science instruction.

2. To study the improvement in both content knowledge and language proficiency with the CLIL pedagogy intervention in mathematics instruction.
3. To study the relationship between mathematics and science scores under the traditional teaching method.
4. To study the relationship between mathematics and science scores under the CLIL pedagogy intervention.

Hypotheses

Ho1 There is no statistically significant improvement in both content knowledge and language proficiency with the CLIL pedagogy intervention in science instruction.

Ho2 There is no statistically significant improvement in both content knowledge and language proficiency with the CLIL pedagogy intervention in mathematics instruction.

Ho3 There is no statistically significant relationship between mathematics and science scores under the traditional teaching method.

Ho4 There is no statistically significant relationship between mathematics and science scores under the CLIL pedagogy intervention.

Methodology

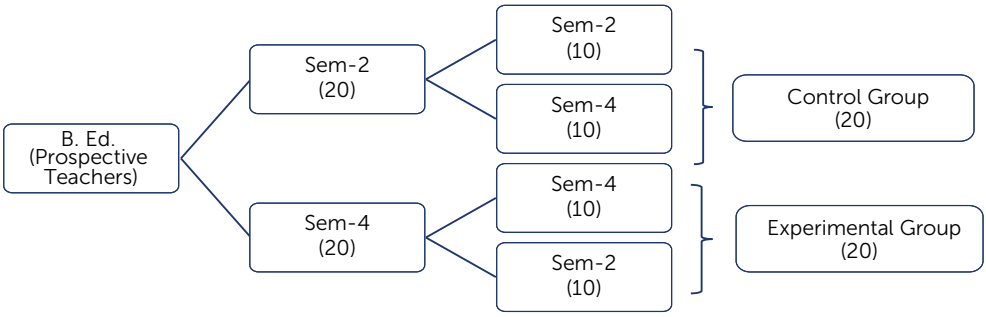
Research Design

The study followed quasi-experimental Pre and Post-test Design.

Time Duration: One Week				
Random Sampling	Control Group	Pre-test	Traditional Teaching Method	Post-test
Random Sampling	Experimental Group	Pre-test	CLIL Intervention	Post-test

Sample

The sample of the study included 40 prospective teachers of semester 2 and 4 of B. Ed. Course from the Department of Education, Chitkara University. Random sampling was done to create two groups, each consisting of 20 members, with an equal distribution from Semester 2 (10) and Semester 4 (10) in both the control and experimental groups.



Data Collection Methods

The study followed a mixed-methods approach. Prospective teacher's language proficiency and content knowledge was measured through a content specific teacher made test for quantitative analysis and survey of attitude of teachers towards CLIL pedagogy was done through interview, classroom observations and a questionnaire. Ethical approval was obtained prior to data collection and participation was voluntary with informed consent from all prospective teachers. Anonymity and confidentiality of participants' data were strictly maintained throughout the study.

Data Analysis

Quantitative data was analyzed using t-tests to measure score differences in Science and Mathematics between the control and experimental groups. Pearson Product Moment Correlation tested the relationship between achievements in both subjects. Qualitative data from interviews, observations, and surveys explored prospective teachers' attitudes towards the CLIL pedagogy. The qualitative data from semi-structured interviews was analyzed by reducing categories and clustering similar concepts into themes.

The CLIL Process

The sample was divided into two groups: the control group received traditional teaching (primarily teacher-centred lecture method), while the experimental group was taught using the CLIL pedagogy for Mathematics and Science. The CLIL content was developed by the Science, Mathematics, and Language teachers. The study lasted one week, with two periods daily for science and mathematics. Post-tests assessing content knowledge and language proficiency in Target languages (TL), English and Hindi were administered to both groups on the last day to measure learning outcomes.

The CLIL Process for Mathematics

The mathematics instructor took the concept of Complementary and Supplementary Angles from the text book prescribed for grade VI in Indian schools by National Council for Educational Research and Training (NCERT). The content was delivered for 5 days followed by post-test on the 6th day.

Day 1

The instructor of mathematics began the intervention with the basic concept of a line, a line segment and a ray.

Introducing Mathematical Concept-1 (a line)

'A line is a straight path that extends infinitely in both directions.'

Explanation in TL (English)

Then she explained the meaning of infinite (something that has no limits or end) English language. For example – The universe is believed to be infinite, stretching beyond what the human mind can comprehend.

Explanation in TL (Hindi)

Thereafter, the teacher made them understand the meaning of infinite ("अनंत") in Hindi language. उदाहरण के लिए – 'आसमान में अनंत तारे हैं।'

Introducing Mathematical Concept-2 (a line segment)

Next, the instructor gave the concept of a line segment and explains the meaning of segment both in English and Hindi. 'A line segment is a part of a line that has two end points.' For example, point A and point B. (using blackboard)

Explanation in TL (English)

Teacher explains the meaning of 'segment' using some examples – 'A segment is a part of a whole, usually with defined boundaries.

Explanation in TL (Hindi)

गणित में 'रेखाखंड' (Line Segment) दो बिंदुओं (points) के बीच की सीधी रेखा होती है। उदाहरण के लिए- बिंदु A और बिंदु B। Segment का अर्थ है 'खंड'. उदाहरण के लिए – 'एक रेखा खींचने पर, उसका एक छोटा सा हिस्सा रेखा खंड कहलाता है।'

Introducing Mathematical Concept-3 (a Ray)

'A ray is a line that starts at a single point and extends infinitely in one direction.' (using blackboard). The meaning of word 'infinite' is repeated as in case of the concept on – a line.

Day 2

The mathematics instructor introduced the concept complementary angles along with synonyms (in English) and पर्यायवाची शब्द (in Hindi).

Introducing Mathematical Concept-4 (complementary angles)

The mathematics instructor introduced complementary angles using a visual teaching aid and explained, 'Two angles are complementary if the sum of the angles is equal to 90°.' For example, a 30° angle and a 60° angle are complementary because their sum is 90°

Explanation in TL (English)

She further explained students the difference between the commonly used word 'complimentary' and 'complementary'. 'Complementary' means two things that complete or enhance each other when combined as in case of angles whereas 'Complimentary' means expressing praise or admiration.

Explanation in TL (Hindi)

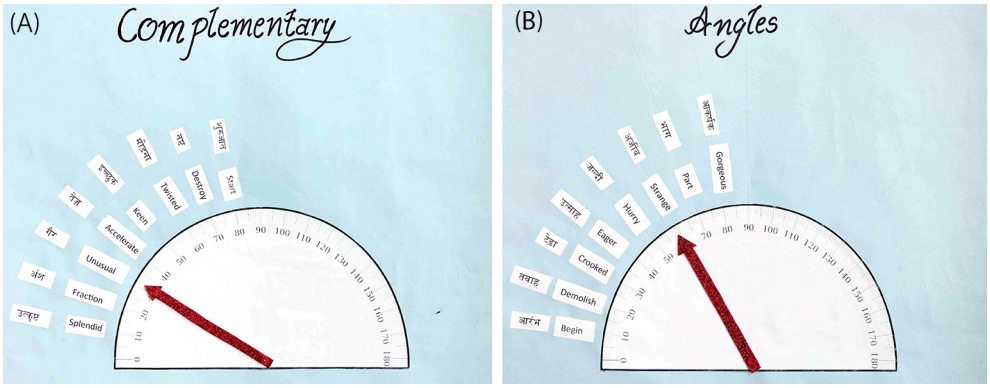
She explained the same concept in Hindi language with emphasis on the meaning of the word 'complementary'. 'complementary' or 'पूरक' का मतलब है दो ऐसी चीजें जो एक-दूसरे को पूरा करती हैं या मिलकर एक-दूसरे को बढ़ाती हैं। Complimentary का मतलब है – एक प्रशंसात्मक टिप्पणी

She then asked students to call out some complimentary words and introduced the synonyms (English) and पर्यायवाची शब्द (Hindi). She explained that these are used to avoid repetition of the same words in a text. This was followed by an interactive activity on Day 3.

Day 3

Activity on complementary angles (Math) synonyms (English) and पर्यायवाची शब्द (Hindi)

The mathematics instructor displayed two chart papers on the blackboard with pictures of protractors (A and B) pasted on them. First chart contained English and a Hindi word written on each angle of the protractor ranging from 0° to 90° and second chart paper had synonym/ पर्यायवाची शब्द word written on their complementary angles. The activity was carried out in three steps. In the first step, participants were called near the display board one by one and were asked to choose any one angle from protractor-A and identify its complementary angle on the another. In the second step, they were asked to read the word written on the selected angle on protractor-A and then read aloud the synonym written on its complementary angle on protector-B. The same procedure was repeated for पर्यायवाची शब्द (Hindi), thereby giving them enough drill and practice in vocabulary of both the target languages.



Picture 1 Activity on Complementary Angles

Day 4

The mathematics instructor introduced the concept of conjunctions (English) and संयोजक शब्दों (Hindi) along with the teaching of supplementary angles.

Introducing Mathematical Concept-5 (supplementary angles)

The mathematics instructor introduced supplementary angles using a visual teaching aid. 'Supplementary angles are those angles that sum up to 180 degrees.' For example – A 50° angle and a 130° angle are supplementary because their sum is 180°

Explanation in TL (English)

She further explained students literal meaning of the word 'supplementary'. Supplementary' refers to extra or additional resources, information, or items that help improve

the main content just like how conjunctions in English work by connecting words, phrases or clauses to make sentences complete and more meaningful.

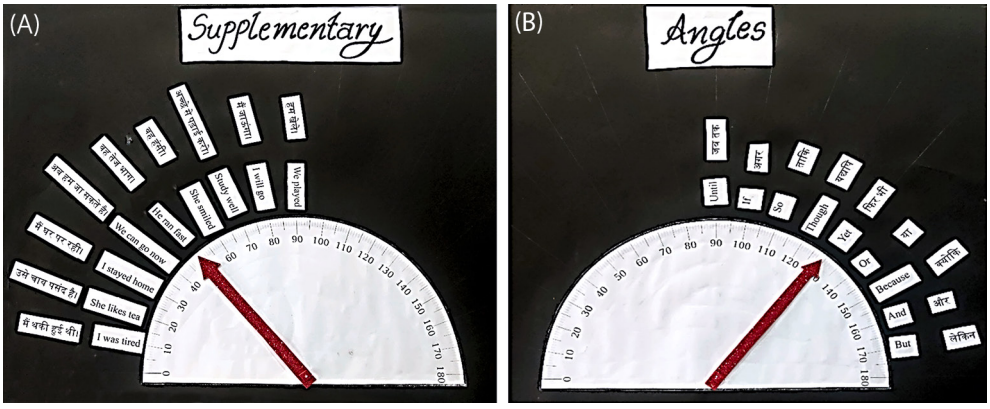
Explanation in TL (Hindi)

She explained the same concept in Hindi language with emphasis on the meaning of the word 'supplementary'. Supplementary or 'अतिरिक्त' का मतलब होता है ज़्यादा, अधिक या बचाकर रखा गया जो मुख्य चीज को बेहतर या पूरा करने में मदद करती हैं, जैसे – हिंदी में संयोजक शब्द वाक्य को जोड़कर उसे अधिक स्पष्ट और सार्थक बनाते हैं।
She then introduced the conjunctions (English) and संयोजक शब्द (Hindi). She explained that these are words that connect words, phrases or clauses in a sentence to make it syntactically correct. This was followed by an interactive activity on Day 5.

Day 5

Activity on supplementary angles (Math) conjunctions (English) and संयोजक शब्द (Hindi)

The mathematics instructor displayed two chart papers on the blackboard with pictures of protractors pasted on them. First chart contained English and Hindi phrases written on each angle of the protractor ranging from 0° to 90° and second chart paper had conjunctions/ संयोजक शब्द written on their supplementary angles ranging from 100° to 180°. The activity was carried out in three steps. In the first step, participants were called near the display board one by one and were asked to choose any one angle from protractor-A and identify its supplementary angle on the another. In the second step, they were asked to read the phrase written on the selected angle on protractor-A and then read aloud the conjunction written on it supplementary angle on protractor-B. The same procedure was repeated for संयोजक शब्द (Hindi), thereby giving them enough drill and practice in sentence formation in both the target languages.



Picture 2 Activity on Supplementary Angles

Day 6 The post-test was administered.

The CLIL Process for Science

The science instructor took the concept of three food groups for grade VI. Day 1 was spent in the discussions about energy giving or ऊर्जा देने वाला भोजन (Hindi) and food items that belong to this group drilling both in English and Hindi language, followed by body building food or शरीर निर्माण भोजन (Hindi) on Day 2, and protective food or सुरक्षात्मक भोजन (Hindi) on Day 3. On day 4, she connected the science concept with Indian culture by discussing staple food found in its different states. Day 5 observed an activity wherein participants revised the terms introduces in both target langiages using a tabular representation. A post-test was conducted to test the learning outcome both in content knowlege and language proficiency on Day 6.

Picture 3 Content on Food Groups in target languages

TL: English	TL: Hindi	TL: English	TL: Hindi	TL: English	TL: Hindi
Energy giving	ऊर्जा देने वाला भोजन	Body building	शरीर निर्माण भोजन	Protective Food	सुरक्षात्मक भोजन
Sugar	चीनी	Pulses (gram, peas)	दाल (चना, मटर)	Fruits and Vegetables	फल और सब्जियाँ
Wheat	गेहू	Eggs	अंडे	Carrots	गाजर
Butter	मक्खन	Milk	दूध	Strawberries	स्ट्रॉबेरी
Oil	तेल	Fish	मछली	Grapes	अंगूर
Rice	शहद			Oranges	संतरे
	चावल			Almonds	बादाम
				Walnut	अखरोट
Cultural importance					
Major states:	Uttar Pradesh		West Bengal		Rajasthan
मुख्य राज्य:	उत्तर प्रदेश		पश्चिम बंगाल		राजस्थान
Staple food crop	wheat		rice and fish		pearl millet
प्रमुख भोजन	गेहू		चावल और मछली		बाजरा

Analysis of Data

Quantitative Analysis

Objective 1. To study the improvement in both content knowledge and language proficiency with the CLIL pedagogy intervention in science instruction.

Ho1. There is no statistically significant improvement in scores with the CLIL pedagogy intervention in science instruction.

The improvement in the prospective teacher's scores in both content knowledge and language proficiency with the CLIL pedagogy intervention in science instruction was analyzed for statistical significance. The *t*-test was conducted to compare the pre and post-test scores obtained in science by the control and experimental group.

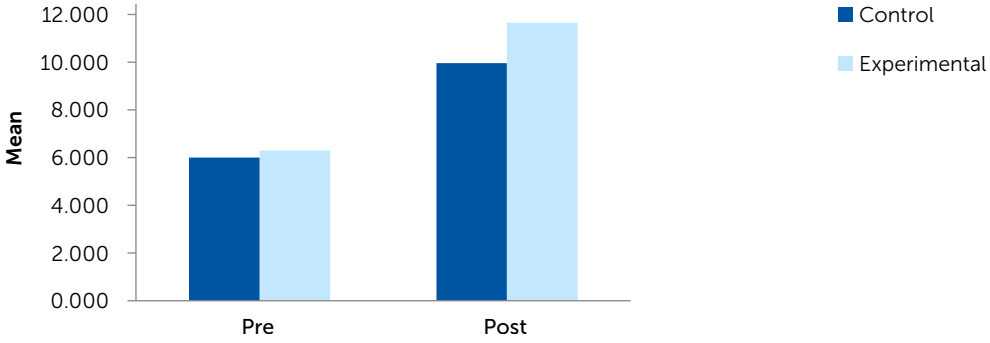


Figure 1 Graphical Representation of Difference between Pre and Post-test Scores of Control and Experimental Group in Science

Table 1 Difference between Pre and Post-test Scores of Control and Experimental Group in Science

Group		*N*	Mean	Std. Deviation	*t*-value	df	*p*-value
Science-Pre	Control	20	6.000	1.777	.547	38	.587
	Experimental	20	6.300	1.689			
Science-Post	Control	20	9.950	2.139	2.912	38	.006**
	Experimental	20	11.650	1.496			

Pre-test Score Analysis

The results from Table 1 and Figure 1 indicate that the mean score for the control group (M = 6.00, SD = 1.777) is significantly lower than that of the experimental group (M = 6.300, SD = 1.689), with mean difference of t (38) = 0.547, p = .587**.** Since the p-value (0.587) is greater than the conventional level of significance (0.05), which suggests that there is no statistically significant difference between the control and experimental group before the intervention. It suggests that both groups had similar baseline performance.

Post-test Score Analysis

As shown in table1 and Figure 1, the results indicate that the mean score for the control group (M = 9.95, SD = 2.139) is significantly lower than that of the experimental group (M = 11.65, SD = 1.496), with mean difference of t (38) = 2.912, p = .006**.** Since the p-value (0.006) is less than the conventional level of significance (0.05), which suggests that there is a statistically significant difference between the two groups, indicating that the experimental group had a meaningful impact on science scores with CLIL intervention they had received for one week. Therefore, null hypothesis 1 is rejected.

Objective 2. To study the improvement in both content knowledge and language proficiency with the CLIL pedagogy intervention in mathematics instruction.

Ho2. There is no statistically significant improvement in scores with the CLIL pedagogy intervention in mathematics instruction.

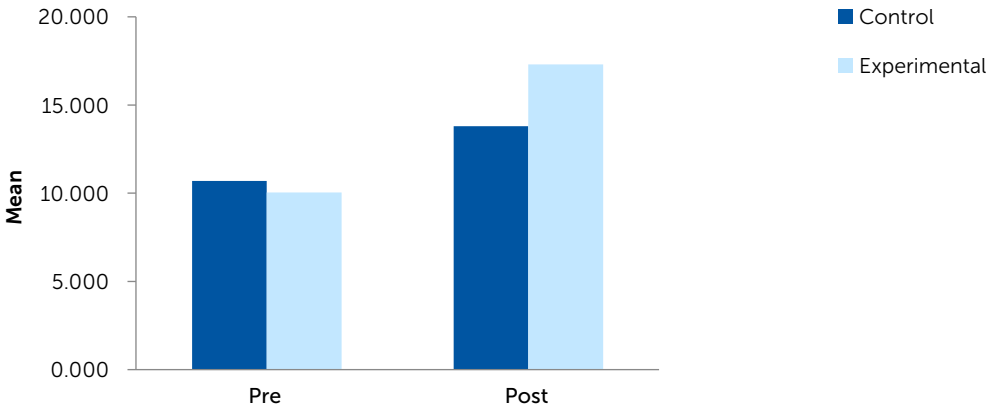


Figure 2 Graphical Representation of Difference between Pre and Post-test Scores of Control and Experimental Group in Mathematics

Table 2 Difference between Pre and Post-test Scores of Control and Experimental Group in Mathematics

Group		*N*	Mean	Std. Deviation	*t*-value	df	*p*-value
Mathematics-Pre	Control	20	10.700	3.358	.696	38	.490
	Experimental	20	10.050	2.481			
Mathematics-Post	Control	20	13.800	3.820	3.308	38	.002**
	Experimental	20	17.300	2.793			

The improvement in the prospective teacher's scores in both content knowledge and language proficiency with the CLIL pedagogy intervention in mathematics instruction was analyzed for statistical significance. The *t*-test was conducted to compare the pre and post-test scores obtained in mathematics by the control and experimental group.

Pre-test Score Analysis

The results from Table 2 and Figure 2 indicate that the mean score for the control group ($M = 10.700$, $SD = 3.358$) is significantly higher than that of the experimental group ($M = 10.050$, $SD = 2.481$), with mean difference of $t\ (38) = 0.696$, $p = .490$**.**

Since the *p*-value (0.490) is greater than the conventional level of significance (0.05), which suggests that there is no statistically significant difference between the control and experimental group before the intervention. It suggests that both groups had similar baseline performance.

Post-test Score Analysis

As shown in table 2 and Figure 2, the results indicate that the mean score for the control group ($M = 13.80$, $SD = 3.820$) was significantly lower than the mean score for the experimental group ($M = 17.30$, $SD = 2.793$), $t\ (38) = 3.308$, $p = .002$.

Since the *p*-value (0.002) is less than the conventional level of significance (0.05), the difference between the two groups is statistically significant, indicating that the experimental group had a meaningful impact on mathematics scores with CLIL intervention they had received for one week. Therefore, null hypothesis 2 is rejected.

Objective 3. To study the relationship between mathematics and science scores under the traditional teaching method.

Ho3. There is no statistically significant relationship between mathematics and science scores under the traditional teaching method.

The Pearson Product Moment Correlation test was conducted to statistically establish the relationship between mathematics and science scores of control group.

Table 3. Pearson Correlation Between Scores in Mathematics and Science for the Control Group

Group			**Mathematics**	**Science**
Control	**Mathematics**	Pearson Correlation	1	.198
		p-value		.402
		N	20	20
	Science	Pearson Correlation	.198	1
		p-value	.402	
		N	20	20

Table 3 shows the Pearson correlation coefficient between mathematics and science is 0.198. This indicates a weak positive correlation, suggesting that as scores in mathematics slightly increase, scores in science also tend to increase, but the relationship is not strong. The *p*-value for the correlation is 0.402, which is greater than the typical significance level of 0.05. This means the correlation is not statistically significant, implying we cannot confidently conclude that there is a meaningful relationship between mathematics and science scores in control group. Therefore, null hypothesis 3 is not rejected.

Objective 4. To study the relationship between mathematics and science scores under the CLIL pedagogy intervention.

Ho4. There is no statistically significant relationship between mathematics and science scores under the CLIL pedagogy intervention.

Table 4 shows the correlation between mathematics and science is 0.303. This indicates a weak to moderate positive relationship, meaning that as scores in mathematics increase, scores in the science also tend to increase, but the relationship is not strong. The *p*-value is 0.193, which is greater than the conventional significance level of 0.05. This suggests that the correlation is not statistically significant, implying we cannot confidently conclude that there is a meaningful relationship between mathematics and science scores in experimental group. Therefore, null hypothesis 4 is not rejected.

Table 4 Pearson Correlation Between Scores in Mathematics and Science for the Experimental Group

Group			Mathematics	Science
Experimental	**Mathematics**	Pearson Correlation	1	.303
		p-value		.193
		N	20	20
	Science	Pearson Correlation	.303	1
		p-value	.193	
		N	20	20

Qualitative Analysis

The following results were obtained on the analysis of the survey questionnaire on the effectiveness of CLIL in enhancing Content and language Proficiency.

Table 5 Responses of Survey Questionnaire on the Attitude of Prospective Teachers Towards CLIL Intervention

S. No.	Items Along with the Percentage of Respondents Under Various Categories of Responses				
1	How familiar are you with CLIL-based teaching?				
	Very familiar	Somewhat familiar	Neutral	Not very familiar	Not at all familiar
	25%	35%	30%	10%	
2	Do you believe C1LIL helped in better understanding of subject content?				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	30%	65%	5%		
3	Do you think CLIL improved bilingual proficiency in Science and Mathematics?				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	35%	60%	5%		
4	How did you feel learning Science/Math using both Hindi and English?				
	Very comfortable	Somewhat comfortable	Neutral	Uncomfortable	Very uncomfortable
	35%	55%	10%		
5	In your opinion, did CLIL make lessons more engaging?				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	30%	60%	10%		
6	CLIL has improved your confidence in using subject-specific vocabulary in both Hindi and English?				
	Yes, significantly	Somewhat	No change	It has made it more difficult	
	40%	60%			

Effectiveness of CLIL in Enhancing Content and Language Proficiency

Table 5 indicates that only 25% of respondents were familiar with CLIL-based teaching, likely due to their exposure to the CLIL lab at Chitkara University. Despite this, 65% agreed that CLIL improved their understanding of subject content, and 60% of the experimental group acknowledged enhanced proficiency in both science and mathematics. Regarding bilingual instruction, 35% felt very comfortable and 55% felt comfortable using both Hindi and English. Most respondents found CLIL lessons engaging, with only 10% remaining neutral. In terms of vocabulary use, 60% reported some improvement in subject-specific terms, while 40% noted significant gains.

Feedback from Subject Teachers who delivered the CLIL-based instructions

Instructors faced several challenges in implementing CLIL pedagogy. The mathematics instructor struggled to balance language and content, while the science instructor noted a lack of resources and found preparation tedious. All teachers involved in designing CLIL lessons (Mathematics, Science, English, and Hindi) felt they needed more training. Additionally, students faced difficulties with dual-language learning.

Feedback on Teaching Mathematics and Science through CLIL Pedagogy

Thematic analysis of the interviews revealed that CLIL intervention positively impacted content knowledge, language acquisition, engagement, and collaboration. However, it also highlighted challenges faced by prospective teachers in its implementation and opportunities to enhance teaching in mathematics and science through CLIL pedagogy.

Table 6 describes the attitude of prospective teachers who were exposed to CLIL intervention (experimental group). They generally provided positive feedback on teaching Mathematics and Science through CLIL Pedagogy.

Table 6 Attitude of Prospective Teachers towards CLIL Intervention

Themes	Coding	Occurrences
A. Positive Feedback on Teaching Mathematics and Science through CLIL Pedagogy		
1. Enhanced Conceptual Understanding	• Use of bilingual resources has made complex scientific and mathematical ideas more accessible	8
2. Language Development and Bilingualism	• Exposure to both English and Hindi terms have enriched vocabulary • Using Hindi synonyms alongside English terms enhanced comprehension and encouraged smoother transitions between subjects.	8
3. Engaging and Interactive Learning Environment	• Encouraged active participation and engagement in classroom discussions. • Creative teaching aids made lessons more stimulating and participatory.	8

Themes	Coding	Occurrences
4. Cognitive and Critical Thinking Skills	• The dual focus on content and language encouraged analytical skills. • Students develop the ability to connect concepts across disciplines.	5
5. Collaboration and Intercultural Competence	• CLIL activities promoted collaborative learning. • It developed a greater respect for multilingualism by engaging with both Hindi and English in academic contexts.	5
6. Pedagogical Impact on Teaching Effectiveness	• Teachers found it rewarding to see participants grasp both subject matter and language. • The success of CLIL reaffirms its value in modern education.	6
B. Challenges in Teaching Mathematics and Science through CLIL Pedagogy		
1. Student Engagement and Inclusivity	• Some students struggled to participate fully • Need for inclusive teaching strategies	5
2. Language Acquisition and Vocabulary Development	• Constraints of learning spaces affected language learning • Additional language support needed for complex topics	7
3. Teacher Expertise and Training	• Subject matter experts needed to be proficient in both mathematics and the target language • Need for rigorous planning and collaboration among teachers • Teacher's training required	7
4. Balancing Content and Language Instruction	• Challenge in maintaining an equal focus on content delivery and language development • Difficulty in preparing and assessing dual-focused resources	8
5. Resource Availability and Accessibility	• Non availability of sufficient well-designed materials to support CLIL teaching • Lack of resources that effectively cater to both content and language objectives	6
6. Time Constraints and Workload	• CLIL lessons require extensive preparation, slowing syllabus completion • Additional workload for teachers (copy checking, revision worksheets, curriculum management) • Limited feasibility of using CLIL for all chapters	5
C. Scope for Enhancing the Teaching of Mathematics and Science through CLIL Pedagogy		
1. Ensuring Lesson Continuity and Coordination	• Maintained a seamless flow in lesson delivery • Enhancing cohesion for a more engaging learning experience	6
2. Increasing Classroom Interaction and Engagement	• Encouraging more dialogue and participation • Enhancing student collaboration for a more interactive environment	8

Themes	Coding	Occurrences
3. Strengthening Teacher Proficiency and Training	• Improving educators' proficiency in both content and language • Providing continuous professional development • Equipping teachers with skills to balance language and subject instruction	6
4. Leveraging Technology for Enhanced Learning	• Utilizing interactive digital resources and simulations • Integrating language learning apps for additional scaffolding	5
5. Incorporating Cultural Elements in CLIL Instruction	• Connecting subject content with real-world cultural contexts • Using cultural integration to deepen conceptual understanding	7

Discussions

This study found confirmatory evidence that the CLIL intervention had a significant positive impact on students' learning in science and mathematics. For both subject areas, the experimental group had a greater mean score post-test than the control group, (Science- M = 11.65 and Maths- M = 17.3), which is consistent with previous research showing CLIL's potential to improve subject knowledge and language knowledge at the same time (Lasagabaster & Sierra, 2010; Pérez-Cañado, 2012). Similar improvements to academic attainment through CLIL have been documented in STEM (science, technology, engineering and maths) contexts (Dalton-Puffer, 2013), where including language objectives provides deeper conceptual understanding while maintaining learner engagement to build knowledge.

The enhancement of mathematics performance also supports previous evidence that CLIL has the ability to promote cognitive development through dual processing of content and language (Marsh, 2012). This dual focus can drive more active meaning making, logical reasoning and problem-solving methods (Coyle et al., 2010). In the present study, the performance of the experimental group contributes to these claims and reaffirms the CLIL benefits are not limited to linguistically heavy subjects, but also to more abstract and symbolic domains like mathematics.

The weak positive correlation in the control group between science and mathematics scores, which had no statistical significance, mimics the trends discussed in studies in which content areas are delimited and little interdisciplinary support takes place (Navés & Muñoz, 1999). By contrast, the weak to moderate correlation in the experimental group, again with no statistical significance could point towards cross subject support when utilizing CLIL strategies. CLIL has been shown to support transferable skills and integrative thinking across subjects (Sylvén & Värnum, 2015) but the data collected in the current study suggest that firmer evidence and claims would necessitate a larger sample and/or more weeks of intervention.

Information from both students and teachers in the present study corroborates previous findings that CLIL develops greater learner engagement, critical thinking and enculturation (Mehisto et al., 2008; Meyer, 2010). The evidence reported here supports the notion that CLIL provides for a more interactive classroom climate that supports collaboration and deeper modes of processing concepts. The challenges of balancing the content and language demands and the increased amount of preparation time are documented in previous studies (Costa & D'Angelo, 2011; Dafouz & Guerrini, 2009). The persistence of these challenges in the present study supports the need to provide professional development to teachers and possibly targeted investment in resources.

Overall, these findings support the academic literature endorsing CLIL as a viable approach to STEM education, and it also points to continued barriers to the wider sustainability of CLIL in STEM education. By also integrating language and content learning, CLIL seemingly addresses both the academic and linguistic goal in ways that could prepare students for the knowledge economy within globalization context.

Conclusion

This study demonstrates robust evidence for the positive impact of Content and Language Integrated Learning (CLIL) on student outcomes in science and mathematics. The substantial improvements outlined for the experimental group suggests that the combination of content and language aims leads to improved understanding of concepts, sustained interest, and cognitive development. The evidence suggests that CLIL enhances 21st-century skills, such as team collaboration, critical thinking and intercultural competence, suggesting a useful pedagogy to help students in a globalised world. Qualitative feedback shows that students value a more interactive and student-centred learning experience, while teachers valued modified strategies. There are challenges associated with this method of pedagogy, namely additional preparation time and a degree of professional learning to adequately balance both content and language instruction. If teacher development programs as well as positive policy change are used to support novice CLIL practitioners, it could become broadly used across STEM education.

In summary, given the ability of CLIL to promote language proficiency and content knowledge, we recommend it be put into practice more broadly in schools, particularly where bilingual or multilingual competence is a function of the curriculum.

Suggestions for the further Research

The study found a weak to moderate positive correlation between mathematics and science post-test scores, suggesting the need for further research with a larger sample. It also showed overall gains in post-test scores for both control and experimental groups, indicating potential for separate studies on content and language proficiency gains. Future research could explore CLIL implementation in subjects like history, civics and economics, as well as the use of Hindi, a widely spoken but less commonly written

language and the introduction of a third language, native or foreign for Grade VI students in Indian schools. A solution-oriented study addressing challenges faced by CLIL teachers would also be valuable. Additionally, long-term impact studies, investigations into effective teacher training models and the development of CLIL specific teaching materials are recommended.

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