A Comparative Study on L2 Teaching in Engineering Universities from the Perspective of CLIL: A Practical Exploration Based on College Physics

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***Abstract*—The Content and Language Integrated Learning (CLIL) approach has been increasingly favored globally. However, its application and empirical research in higher education are relatively scarce in China. This study adopted an experimental research method and, from a diachronic perspective, conducted an in-depth study on 243 freshmen participating in international cooperative education programs from a domestic engineering institution. It aims to compare the impacts of the CLIL teaching model based on University Physics and the ordinary academic model regarding students' foreign language acquisition and L2 learning motivation. The results show that after one semester of study, foreign language teaching under the CLIL model can achieve remarkable results in enhancing students' L2 writing skills, stimulating their L2 learning motivation, and increasing their interest in L2 learning. This study will provide a solid practical basis for further validating the significant value of the CLIL model in domestic college English teaching and subject-based teaching, and offer valuable reference for promoting the reform of college English teaching under the background of the construction of new liberal arts.**

***Keywords*—Content and Language Integrated Learning (CLIL), L2 writing, L2 motivation, college physics**

I. Introduction

Since the mid-1990s, Content and Language Integrated Learning (CLIL) has been widely recognized and applied in the field of bilingual education in Europe [1]. As an innovative teaching method, CLIL, with its unique educational objective of promoting the synchronous development of foreign language proficiency and subject knowledge, has quickly attracted the attention of the education community, the academic arena, and administrative departments. The rise of this teaching method, on the one hand, conforms to the profound transformation of foreign language teaching concepts. The traditional teaching model, which is centered on language functions from the perspective of structuralism, has been shifted to a new teaching model that focuses on language content and communicative competence [2]; on the other hand, the popularity of CLIL is also closely related to the rapidly accelerating globalization and increasing multilingualism. This teaching model not only aligns with modern society's demand for versatile talents, but also effectively cultivates globally-minded individuals with strong cross-cultural competencies.

This interdisciplinary teaching method involves collaboration among multiple stakeholders, and it has long been valued by scholars from Europe, the United States, and some Asian countries [3, 4]. So far, it has achieved many fruitful results in fields such as foreign language teaching, subject teaching, and the cultivation of students' abilities. Based on this, conducting research on CLIL theoretically helps to expand the understanding of foreign language teaching concepts and enrich the relevant achievements of subject teaching research in a foreign language. In teaching practice, this approach helps bridge the gap between foreign language acquisition and disciplinary knowledge, facilitating a paradigm shift from "learning a foreign language" to "learning through the foreign language". It enhances the effectiveness of both language instruction and subject teaching, thereby promoting the comprehensive development of students' holistic competencies.

II. Literature Review

The CLIL model originated in Europe in the 1990s. At that time, the process of European integration was advancing rapidly, and this development trend led to a sharp increase in the society's demand for multilingual talents [5]. Nordic countries such as Finland and Sweden took the lead in carrying out practices to improve students' language application abilities and international competitiveness. In the early days, the education departments mainly tried to teach some individual subjects in a foreign language. With the deepening of the practice, a systematic CLIL teaching concept and model gradually took shape. After that, CLIL was quickly popularized in other European countries. For example, countries like the Netherlands and Spain successively incorporated it into their education systems. Entering the 21st century, CLIL has received much attention on a global scale. Some countries in South America and Asia have also begun to draw on it and carry out relevant practices, and the conceptual depth and practical applications of this approach has been continuously broadened.

CLIL is not just a simple integration of foreign language learning and subject content, but also a product of the development of foreign language education in the context of the new era. In recent years, a substantial number of international studies have primarily focused on the acquisition of foreign language skills within the CLIL framework. Goris *et al.* believed that CLIL had a significant effect on the development of students' language skills. Students who received the CLIL teaching model were

significantly better than those in traditional teaching in terms of vocabulary size, grammatical accuracy, and comprehensive abilities [6]. For example, in Germany, students participating in CLIL projects generally achieved high scores in international language tests [7]. In addition, the research from some international scholars also focuses on the integration of language learning and subject knowledge, especially on the in-depth understanding of subject content. For instance, Dalton-Puffer proposed the interdisciplinary research construct of "cognitive discourse functions" [4], which examines the specific linguistic roles played in CLIL instruction from a metalinguistic perspective. Meanwhile, in Finland, an empirical study of a natural science course based on the CLIL model showed that when students learned scientific knowledge in English, they could not only improve their English proficiency, but also gain a deeper understanding and better application of scientific concepts. Therefore, they were able to perform better in subject competitions [8]. Thirdly, recent theoretical developments in CLIL have witnessed progressive conceptual expansion, with emerging emphasis on the pedagogical integration of intercultural communicative competence, the skills that exemplify intercultural learning (observation, analysis, reflection, interpretation, perspective-taking, evaluation, and so on) [9]. Research showed that the CLIL model helped students to be exposed to a large amount of knowledge and information from different cultural backgrounds, and thus promoted the progressive improvement of cross-cultural communication abilities, especially students' international orientation, intercultural competence, and global citizenship [10]. For example, in international schools in France, students communicated and cooperated with classmates from different countries through CLIL courses, thus significantly improving their understanding and tolerance of diverse cultures [11]. Ang and Van Dyne's research further reveals that following an 18-week intervention utilizing a self-designed CLIL coursebook for cross-cultural teaching in the hospitality and tourism industries, learners demonstrated a significant enhancement in intercultural competence, as measured by a validated cultural quotient survey [12].

In comparison, research on CLIL in China started relatively late, but certain progress has been made in recent years. On the one hand, in the field of basic theoretical research, scholars have deeply interpreted and localized the concepts and connotations of CLIL [13], enhancing the understanding and comprehension of the CLIL model within the Chinese educational sphere. On the other hand, relevant empirical research has been emerging continuously, with the most important being in-depth explorations of the teaching reform of English majors [14, 15]. A small number of scholars and educators have attempted to introduce the CLIL model into the teaching of different subjects and explore the feasibility for the tertiary institution in China. For example, Ye *et al.* explored the application of the CLIL model in domestic medical education and achieved good teaching results [16]. Weng explored the application of the CLIL model in college Japanese language teaching and found that it was easier to stimulate students' critical and creative thinking through CLIL [17].

Overall, CLIL model has received favorable evaluations of its teaching effectiveness in multi-dimensional assessments abroad. However, the research progress in this regard in China is relatively slow. Currently, most existing studies focus on the theoretical exploration of the teaching reform of English majors, and there is a lack of in-depth measurement from an empirical perspective of the actual effectiveness of the CLIL model in college English teaching in China. Therefore, it is impossible to intuitively and accurately demonstrate the impact of this model on domestic English education. For this reason, the academic community urgently needs to embark on a journey of in-depth exploration relying on the CLIL model teaching in different disciplines.

Therefore, based on the existing research at home and abroad, this paper attempts to answer the following two questions: (1) Compared with conventional academic English teaching, can the CLIL model relying on college physics significantly improve students' English writing ability? (2) Compared with conventional academic English teaching, can the CLIL teaching model enhance students' motivation for English learning?

III. Methodology

To deeply answer the above two questions, this study uses the experimental research method to carry out relevant explorations and investigates the teaching situation of the CLIL model in an international cooperation project of a key engineering university in Northeast China (see Fig. 1). The researchers selected four intact first-year classes (total n=125) from the Sino-UK International Cooperation Program (4+0 model) as the experimental group, implementing CLIL approach. For comparison, four parallel first-year classes (total n=118) from the university's 3+1 Sino-UK International Cooperation Program served as the control group, continuing with standard academic instruction. All participants were automation engineering majors, with no statistically significant difference in English proficiency scores (as measured by the National College Entrance Examination) between the experimental and control groups ($M_{CLIL\ group}$=125.4/150; $M_{academic\ group}$=123.6/150). To ensure comparability, we standardized English instruction at 64 hours for both experimental and control conditions and 2 international teachers were employed in the delivery of subject courses during the experimental semester.

In the experimental group, instructors implemented CLIL-based pedagogy by delivering English instruction through college physics content. The instructors selected the self-compiled textbook "Academic English for Engineering", which focuses on physical content such as optics, electromagnetism, and thermodynamics. Through real-task design and situational teaching, students' learning experience was enhanced, which helped them improve their English application ability while learning college physics knowledge. Taking Chapter 5 "Entropy and Disorder" as an example, its core content revolves around the relevant content of thermodynamics. Through the texts "What is Entropy?" and "Entropy and Disorder", teachers deeply explained the principle of entropy increase and the Second Law of Thermodynamics. Regarding assignments, students

were required to: (1) conduct literature searches on relevant physics topics, (2) prepare academic reports, and (3) deliver 3–4-minute English presentations. This tripartite task design aimed to enhance students' engagement with physics content through English-medium academic practices. (Table 1)

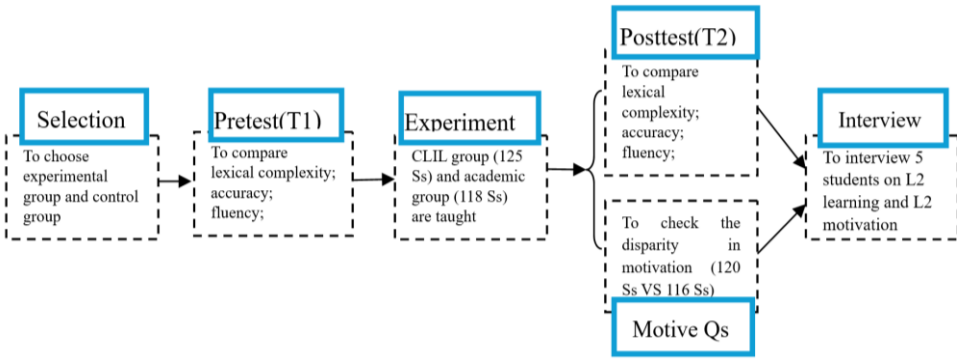

Fig. 1. Flow chart of sampling and data collection

Table 1. Activities in CLIL teaching

Language Skills	Activity or assignment
Listening	Essay listening "*What is Entropy?*" from the textbook and TED speeches such as *Entropy, order and the theory of the multiverse (by ELEW and Marcus Miller)*
Speaking	Heating-related English presentation in 3–4 minutes after self-studying journal papers assigned by teachers.
Reading	Essay of Entropy and Disorder, and chapters17-20 from textbook *University Physics with Modern Physic*
Writing	Summary writing of a journal paper and answer questions from the textbook such as *How does entropy influence your life*?

In comparison, during the teaching process in the control group, instructors adopted a conventional pedagogical approach by focusing on the content of the IELTS exam and deeply engaged in English teaching practices centered on academic scenarios, aiming to enhance students' skills in the four key dimensions: listening, speaking, reading, and writing. To further improve teaching efficiency, the teachers made full use of multiple platforms such as iWrite and Chaoxing Platform by designing scaffolded exercises online to reinforce language skills through technology-enhanced learning pathways.

Table 2. Means and standard deviations of fluency, accuracy and lexical complexity

	T1 (Academic)	T1 (CLIL)	T2 (Academic)	T2 (CLIL)
Fluency	10.34	10.55	11.24	12.25
	(4.29)	(4.51)	(3.65)	(4.02)
Accuracy	0.48	0.52	0.42	0.61
	(0.21)	(0.20)	(0.25)	(0.21)
Lexical complexity	70.31	70.86	71.28	78.69
	(19.79)	(20.74)	(20.56)	(21.68)

Note. T1=test before the experiment; T2=test after the experiment, SDs are given in parentheses.

For the first research question, during the English Placement Test in August 2024, the students of the eight classes were all required to complete an argumentative essay of about 250 words within 40 minutes. The topic was "*Analysis of the Advantages and Disadvantages of Robots for the Development of Human Society*". This writing task, designated as Task 1 (T1), underwent systematic comparative analysis across the experimental and control groups to evaluate intergroup performance disparities, as shown in Table 2. At the end of December 2024, the students of the eight classes were again required to complete another argumentative essay of about 250 words with a similar topic within 40 minutes. This writing task, designated as Task 2 (T2), also underwent systematic comparative analysis across the experimental and control groups. To conduct a more accurate comparative analysis of the language development of the two groups of students, this study selected three key dimensions of writing output proposed by Skehan, namely complexity, accuracy, and fluency [18] and adopted various methods to collect and analyze the data.

For the study of lexical complexity, this study adopted the WT^2/W model (word types squared divided by the total number of words) proposed by Ong & Jun Zhang for evaluation, as this formula considers the length of texts produced by the learners [19]. For the study of accuracy, this study drew on the concept of T-units proposed by Kellogg to detect the changes in the writing abilities of the two groups. It usually uses the indicator of "the ratio of the number of error-free terminating units to the number of terminating units" for investigation [20]. For the fluency analysis, this study measured it by counting the average number of words output per minute within the writing time [21]. Finally, ANOVA in SPSS 23 was used to compare the three sets of collected data.

For the second research question, this study utilized the CLIL motivation questionnaire developed by Lasagabaster and Doiz, which comprises five dimensions: intrinsic motivation, instrumental motivation, global integration motivation, learning interest, and motivation intensity [22]. The questionnaire consists of 16 items in total. For example, the questions under the dimension of motivation intensity include "*Even if I don't like what I'm doing, I still work hard in English class*". To improve the statistical effectiveness, the original instrument was first translated into Simplified Chinese following Language Industry Standards Association (LISA) guidelines, followed by

bilingual expert review to establish semantic equivalence. A back-translation procedure was then implemented by a third-party teacher to verify conceptual consistency. The results of the pilot study showed that the questionnaire had good internal consistency, and the overall reliability coefficient is 0.727, meeting the requirements of measurement reliability. Subsequently, with the help of the Wenjuanxing platform, the researchers distributed the questionnaire to the students for answering online. Finally, 120 valid questionnaires were collected from the CLIL group, while 116 valid questionnaires were collected from the academic group. Afterwards, the researchers randomly sampled and interviewed 5 students in each group, and deeply explored the specific experiences of the students regarding the cultivation of English writing ability and English learning motivation.

IV. Results & Discussion

With respect to our first research question, we conducted a systematic comparative analysis of English writing performance—including fluency, accuracy, and lexical complexity—based on the 486 students' writing samples through ANOVA. Table 2 presents the means and standard deviations for fluency, accuracy, and lexical complexity of learner texts in the T1 of the academic group, T1 of the CLIL group, T2 of the academic group, and T2 of the CLIL group. The ANOVA test revealed no significant differences in fluency across the learners' argumentative essays from the four conditions, [F (3, 482) = 2.11, *n.s.*] (see Table 3).

As for writing accuracy, there was a significant difference when the writing phase and student group changed [F (3, 482) = 12.93, MSE = 219.21, $p < 0.001$, $\eta^2 = 0.46$], with a moderately large effect size. Post hoc Tukey test results indicate that the texts written in the T2 of the CLIL group showed a higher accuracy than those written in the T1 of the CLIL group ($p < 0.041$) and the T2 of the academic group ($p < 0.001$). However, ANOVA test shows there is no significant difference in writing accuracy between the texts of the T1 from the academic group and those from the T2 of the academic group [F (1, 234) = 4.92, *n.s.*].

As for lexical complexity, there was a significant difference when the writing phase and writing group changed [F (3, 482) =26.34, MSE = 5.72, $p< 0.001$, η^2=0.52]. The effect size was medium. Post hoc Tukey test results indicate that the students in the T2 of the CLIL group scored significantly higher for lexical complexity than those in the T1 of the CLIL group ($p < 0.001$) and the T2 of the academic group ($p < 0.001$). There was, however, no significant difference in lexical complexity between the T1 of the academic group and T2 of the academic group [F (1, 234) = 2.76, *n.s.*].

Table 3. Main effects on fluency accuracy and lexical complexity

Dependent Variables	*F*	df	*p*	η^2
Fluency	2.11	3	0.042	0.041
Accuracy	12.93	3	0.000	0.46
Lexical complexity	26.34	3	0.000	0.52

$p < 0.05$

The above results indicate that at the beginning of enrollment, there was no significant difference in writing ability between the two groups of students. However, after one semester of study, compared with the academic class, the CLIL mode can effectively improve students' writing proficiency, especially in terms of lexical complexity and writing accuracy, which has a positive impact on the development of students' writing ability. This improvement may be because students under the CLIL mode can be exposed to and use more abundant high-level physics-related vocabulary, and expand their vocabulary reserves, thus making their English writing more complex and diverse. For example, in the interview, Song said, "*I felt myself exposed to a large number of complex physics vocabulary, such as entropy, quantum, thermodynamic, and other physics words and this contributed to the mastery of etymological root knowledge relevant to the subject matter*". Obviously, this helps to encourage students to express their thoughts with complex vocabulary. Coincidentally, Olsson's research also found that compared with the non-CLIL mode, the CLIL mode could help with the rapid acquisition of academic vocabulary in second language writing [23]. Therefore, students under the CLIL mode are more likely to deeply remember relatively complex academic vocabulary.

In terms of accuracy, students in the CLIL group usually need to read many physics-related documents in English. Through this immersive training in the physical context, students can easily master the subject-specific grammatical structures and academic vocabulary systematically, which helps to improve the language accuracy in their written output. Therefore, after one semester of CLIL, the accuracy of English writing has been significantly improved. This finding corroborates Lahuerta's observation that CLIL learners demonstrate significantly greater improvement in writing accuracy compared to non-CLIL students [24]. As for fluency, students in the CLIL group did not show an obvious advantage, and this finding contradicts the research results of Saladrigues & Llanes [25]. This phenomenon may be attributed to the fact that learning physics content in a foreign language imposes higher cognitive demands on CLIL students. They are used to simultaneously processing language output and content precision, which may lead to slower language output and thus affect fluency in writing. Besides, students in the control group also underwent intensive academic training in English writing through both online and offline platform during the study period. This resulted in significant improvements in their fluency by the end of the semester. Overall findings demonstrate that after one semester of instruction, the CLIL approach proves more effective in enhancing students' writing proficiency, particularly in developing lexical complexity and grammatical accuracy.

For the second research question, this study compared the differences in CLIL motivation between the CLIL group and the academic group in independent t-test across five dimensions: intrinsic motivation, instrumental motivation, and global integrative motivation, among others. As shown in Table 4, there were no significant differences between the two groups of students in the dimensions of intrinsic motivation (t=1.539, p>0.05), global integrative motivation

(t=1.223, p>0.05), and motivational intensity (t=0.978, p>0.05). This finding aligns with the results of Lasagabaster & Doiz's study, which indicates that the CLIL approach does not significantly enhance the learning motivations among learners taught under this model [22]. However, significant statistical differences were observed between the two groups in the dimensions of instrumental motivation (t=2.341, p<0.05) and learning interest (t=1.963, p<0.05).

Table 4. Dimensions of CLIL motivation

	Students	Number	Mean	SD	t	*sig*
Intrinsic motivation	CLIL group	120	3.20	0.66	1.539	0.130
	Academic group	116	2.83	0.55		
Instrumental motivation	CLIL group	120	3.65	0.63	2.341	0.004*
	Academic group	116	3.16	0.55		
Global motivation	CLIL group	120	3.11	0.69	1.223	0.065
	Academic group	116	2.60	0.55		
Learning interest	CLIL group	120	3.17	0.62	1.963	0.008*
	Academic group	116	2.28	0.60		
Motivation intensity	CLIL group	120	2.87	0.63	0.978	0.202
	Academic group	116	2.34	0.60		

$p < 0.05$

The above results indicate that although the CLIL mode cannot enhance all the motivation dimensions of CLIL learners, it can better stimulate students' instrumental motivation. A plausible explanation may reside in the inherent capacity of the CLIL approach to cultivate and sustain instrumental motivation among learners. For example, Li said, "*I need to use English to understand and explain complex physical concepts, experimental procedures, and physical phenomena. And I felt I am connected to the cutting-edge physics knowledge*". This helps students realize that mastering English well is a necessary condition for acquiring advanced scientific knowledge, and thus stimulates the instrumental motivation based on the purpose of acquiring physics knowledge. More importantly, this leads up to more positive self-perception and clearer L2 self-visions [26] compared with their non-CLIL counterparts.

In addition, the CLIL mode can enhance students' interest in English learning. The integrated teaching breaks the dull mode of conventional English instruction paradigm, enabling students to naturally stimulate their inherent interest in second language learning while exploring physical knowledge. This finding is highly consistent with the results of Rumlich's research on CLIL mode in Germany, and it can be mutually verified from aspects such as learning motivation and learning interest [27]. However, the CLIL mode has a relatively limited effect on enhancing students' global integration motivation, intrinsic motivation, and motivational strength. The reason may be that students in both international cooperation programs hold similar sociocultural identification with the target language and already have overly high foreign language learning motivation, and this identification and motivation will not change significantly in the short term. Overall, within the mode of CLIL, students demonstrate notably enhanced instrumental motivation and L2 learning interest throughout their learning progression.

V. Conclusion

By examining specific practices in foreign language teaching within international cooperative programs, this study conducts a diachronic comparison of the differential effects between the CLIL model (anchored in college physics) and conventional academic approaches in foreign language instruction. This study not only provides an in-depth examination of the feasibility and scientific validity of the CLIL model within the Chinese context, but also employs empirical data analysis to conduct a rigorous investigation into its demonstrable effects on enhancing L2 writing proficiency, stimulating L2 learning motivation, and enhancing their interest in foreign language learning. This study further demonstrates that the CLIL approach not only diversifies instructional formats and caters to students' professional development needs, but also continuously enhances their second language (L2) proficiency and enriches disciplinary knowledge. Therefore, this integrated teaching approach offers valuable insights for innovating university English education and refining training frameworks for subject teachers, meriting sustained scholarly investigation. However, due to the limitation of time and energy, this research only focused on CLIL teaching from one Chinese university. Broader replication across diverse universities with varied geographic, institutional, and cultural profiles would be essential to enhance the external validity of the conclusions.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Yu Shougang conceptualized the research idea, designed the study, developed the questionnaire, conducted the interviews, and drafted the manuscript; Yue Tieyan transcribed the recordings, performed the initial data analysis, revised the manuscript, and provided critical feedback; both authors reviewed and approved the final version of the manuscript.

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