Co-developing Science Literacy and Foreign Language Literacy through "Concept + Language Mapping"

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Abstract

Drawing on Lemke's (1990) 'thematic patterns' theory, this research proposes a "Concept + Language Mapping" (CLM) approach and tried it out in an English Medium Instruction (EMI) biology classroom in Hong Kong. Lessons were observed and samples of student work were collected during the intervention with student/teacher interviews conducted afterwards. A quasi-experimental design was also adopted to estimate the impact of the CLM approach. The analysis indicated that CLM facilitated the development of both content and language knowledge.

Keywords: "Concept + Language Mapping" (CLM), Content and Language Integrated Learning (CLIL), English-medium instruction (EMI), Foreign Language Literacy, Science Literacy, Thematic Patterns

1. Introduction

Content and Language Integrated Learning (CLIL) is an educational approach where students learn non-language content subjects through a second/foreign/additional language (L2) (Coyle, Hood, & Marsh, 2010) and it has become a key research domain in bilingual/foreign language education. Previous literature on CLIL largely focused on its various definitions, language and content learning outcomes and pedagogical issues (Cenoz, Genesee, & Gorter, 2013; Dalton-Puffer & Nikula, 2014; Lin, 2016; Llinares, Morton & Whittaker, 2012). Recent studies have begun to explore CLIL teacher education (Cammarata & Ó Ceallaigh, 2018) such as CLIL teachers' knowledge about language (Morton, 2018), professional identities (Dale, Ron, & Verspoor, 2018) and language awareness (He & Lin, 2018). While there is no denying that CLIL involves the teaching of both content and language, it remains a challenge to achieve pedagogical integration of content and language in CLIL classrooms (Dalton-Puffer, 2018; Lin, 2016; Ruiz de Zarobe, 2016). Although researchers have explored the balance between language and content (Cammaratar & Tedick, 2012; Dalton-Puffer, 2013; Lyster, 2007) and conceptualized the integration of the two (Nikula, Dafouz, Moore & Smit, 2016), these studies have mainly drawn on language pedagogy rather than content pedagogy perspectives (Cenoz, 2016; Dalton-Puffer, 2018). A "notable gap" has been "the lack of involvement" of subject specialists in CLIL research (Dalton-Puffer & Nikula, 2014, p.119) incorporating "expert perspectives of subject education researchers" (Dalton-Puffer, 2018, p.386). Echoing the need for both language and subject-specific perspectives on CLIL, Lin (2016) recommended using "thematic patterns", a notion proposed by Lemke (1990) in his seminal work *Talking Science*, to integrate content and language pedagogies across the curriculum.

Science academic literacy is both cognitively and linguistically demanding; hence, learning science is virtually learning a "foreign language" (Wellington & Osborne, 2001). In science classrooms where content subjects are taught in English as an additional language

(EAL), the task of learning is "squared" (i.e. two foreign languages multiplying each other). In this study, we address issues concerning the co-development of science literacy and academic language literacy in English-medium instruction (EMI) science education. Drawing on Lemke's (1990) theory of thematic patterns, we proposed the "Concept + Language Mapping" (CLM) approach as an innovative CLIL pedagogy and pioneered it in an EMI biology class in a secondary school in Hong Kong. The impact of CLM pedagogy is examined and the findings and implications for CLIL teacher education will be discussed.

2. Literature review

This section reviews the research traditions of concept mapping and thematic patterns respectively. They contribute to the theoretical framework for the CLM approach.

2.1 Meaningful learning and concept mapping

Education in all content subjects involves learning of concepts which are traditionally defined as "a perceived regularity in events or objects designated by an arbitrary label" (Novak, Gowin, & Johansen, 1983, p.625). Concepts are seen as abstract but are fundamental for all content subjects, and they remain challenging for classroom teaching. Grounded in the assimilation theory of meaningful learning (Ausubel,1968), Novak et al. (1983) contributed to concept learning by developing the strategy of concept mapping, which has been widely applied in the teaching of various subjects. Concept mapping is believed to facilitate meaningful learning by constructing a spatial and visual representation of interconnected concepts and the hierarchical structure of conceptual knowledge in the human mind (Novak et al., 1983; Novak, 2010).

2.2 Thematic patterns

Although concept mapping has been regarded as a useful meta-cognitive strategy, it has limitations arising from its neglect of the role of language in learning. As pointed out by Novak (2010), concept maps which "strip away all text except for concept labels" may lead to the "lack of clarity for most people" (p. 32). It is also noted that although concepts in concept maps are linked in a meaningful way to indicate the interrelationship between concepts, the concepts themselves may be too abstract for learners to understand. Such mentalistic representations of concepts, according to Lemke (1998), "lacks the necessary vocabulary" to tell teachers what they should do to help students to understand the concepts.

Rather than conceptualizing "concept" as abstract mental representations of objects or events, Lemke (1990) proposed the notion of "thematic pattern", defined as "the pattern of connections among the meanings of words in a particular field of science" (Lemke, 1990, p.12). According to Lemke, each specialized field of human activity has its own unique semantic patterns (i.e. conceptual system). Within each thematic pattern, there are "thematic items" linked by their customary semantic relationships. On one hand, each thematic pattern can be "condensed" and become a thematic item of another thematic pattern at a higher semantic hierarchy; on the other hand, thematic patterns in different parts of the specialized field can be interrelated to form a more complex "thematic nexus" (i.e. a synthesis). In order to communicate ideas, we need to express relationships between the meanings of different thematic items. Language is a system of resources for making meaning and it is used to describe not only the semantic relationships between different thematic patterns but also those within a particular thematic pattern. For example, the concept "photosynthesis" (Figure 1) can be conceptualized as a thematic pattern consisting of "thematic items" (i.e. process, green plants, food, carbon dioxide, water, light energy) connected by different specific "semantic relations" (i.e. TOKEN/TYPE; AGENT/PROCESS; PROCESS/TARGET;

CIRCUMSTANCE: manner/material/condition). The thematic pattern "photosynthesis" can be "condensed" to a thematic item and woven into another thematic pattern expressing the "reason for the importance of photosynthesis" (i.e. the sentence "Photosynthesis is important because it produces food (starch) and releases oxygen for all living things"). The latter thematic pattern may in turn become one of the many logically related themes (thematic units) and be further woven into a text (i.e. "thematic nexus") about "how green plants obtain energy" in a science lesson.

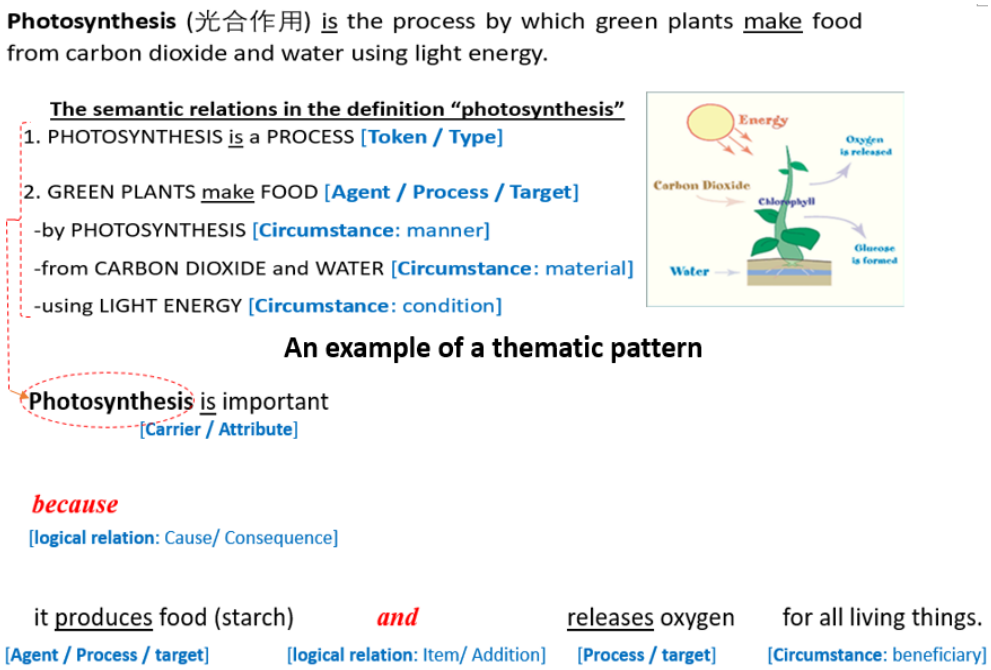


Figure 1: Thematic patterns and semantic relations about photosynthesis

In this way, Lemke's (1990) thematic pattern theory offers teachers a linguistic tool which enables them not only to de-construct/analyse the thematic items and semantic relations within/between different concepts (i.e. thematic patterns) but also, through "theme-weaving", to establish thematic interconnections between different thematic patterns at more than one intermediate thematic nexus (in traditional terms: linking concepts learned in different lessons).

2.3 Thematic-pattern-based "Concept + Language Mapping"

Drawing on Lemke's (1990) thematic pattern theory and previous research findings, the present study extended "concept mapping" (Novak et al., 1983) to a thematic-pattern-based CLM approach (Figure 2) by emphasizing the role of language in concept instruction in CLIL lessons.

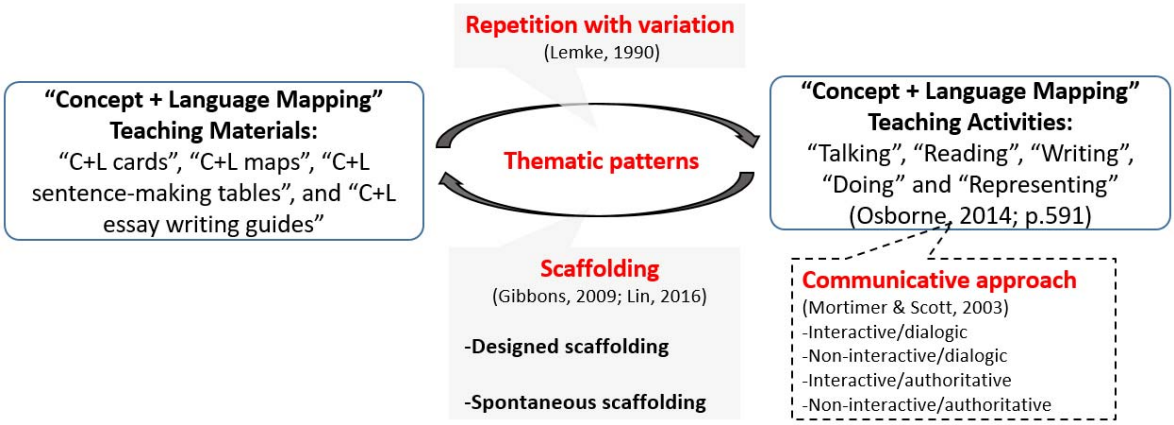


Figure 2: The Thematic-pattern-based CLM Approach

In CLM pedagogy, CLM materials[1] including C+L cards, C+L maps, sentence-making tables and essay writing guides are designed to present the key thematic patterns under a thematic topic. Using these materials and activities, students are enabled to engage with the thematic patterns multiple times through "repetition with variation" (Lemke, 1990). For example, the same thematic patterns in the C+L map "The process of photosynthesis" are presented in the textbook with both verbal texts and graphic diagrams; during CLIL lessons they are introduced by the teacher and discussed among students, and then are read by students in the task sheets. The thematic patterns are further explored in experiments conducted by the students and are written out in their assignments and tests. Through a series of communicative activities --- "re-presenting" (Lemke, 1998), "talking", "reading", "doing" and "writing" (Osborne, 2014, p.591), the thematic patterns focusing on the same thematic topic appear time and again, "with some items and relations similarly expressed and others differently expressed" (Lemke, 1990,

[1] "C+L" is the abbreviation for "Concept + Language", e.g. "C+ L cards" means "Concept + Language cards". Examples of the materials are shown in the Results and Analysis section.

p.227). Such repetition of thematic patterns with variation helps students to understand the abstract conceptual patterns on the one hand and consolidate both content and language knowledge on the other. Both the CLM materials and CLM activities are two core components in the thematic-pattern-based CLM pedagogy. Effective implementation of the pedagogy relies on the scaffolding provided by the teacher who is the designer and instructor of the lessons. The CLM materials are part of the designed scaffolding (Gibbons, 2009; Lin, 2016) prepared by the teacher before the lessons, but they take effect only when they are flexibly activated and used by students themselves during the CLM activities; in other words, the thematic-pattern-based teaching materials must be fully understood (rather than rote-memorized) and flexibly employed during argumentation and inquiry of content knowledge. The role of the CLIL teacher is most significantly reflected in his/her flexible application of both designed scaffolding and spontaneous scaffolding (Gibbons, 2009; Lin 2016) during which the teacher "talks" about content and language knowledge with students through a "communicative approach" that shifts between different combinations of interactive/non-interactive and dialogic/authoritative styles (Mortimer & Scott, 2003) according to different purposes at different stages of CLIL teaching.

4. Methodology

To gauge the potential impact of the thematic-pattern-based CLM pedagogy as well as its feasibility in CLIL classrooms, we developed the following research questions:

1. Does the CLM approach facilitate development of both content knowledge and language knowledge in the EMI biology classroom?

2. What are the processes involved in pioneering the CLM approach in an EMI biology classroom?

4.1 Research design

English remains the socioeconomically dominant language and the most important medium of instruction in Hong Kong even after its handover to China in 1997. Due to high parental pressure for EMI education, many schools offer EMI classes even though there is not enough support provided for students learning content in English (Lin & Man, 2009). This research was conducted in a Secondary 4 (S4) EMI biology class to pioneer the CLM approach to support students' learning of both content and language. Following Reeves' (2000) "development research" framework, the study proceeded in four phases: First, the researchers had pre-intervention interviews with teachers probing what they perceived as teaching and learning challenges; second, the thematic-pattern-based CLM materials (i.e. C+L cards, C+L maps, C+L sentence-making tables, and C+L essay writing guides)[2] were designed by the researchers and reviewed by teachers in different content areas; third, the CLM materials were tried out in lessons by the participating teachers who decided on which materials to use and when to use them; and fourth, the teachers and researchers co-reflected on the CLM pedagogy and improved it in an ongoing process. In the senior biology subject, as the research adopted a quasi-experimental design but there was only one biology class in each grade, the S4 and S5 biology teachers adjusted their teaching scheme so that the same topic "monohybrid inheritance", originally a S5 unit, could be taught to the S4 and S5 classes during the same

[2] The technical terms such as "Agent", "Process", "Target", and "Circumstance" in the analysis of the CLM material examples in Figures 1, 4 and 6 are metalinguistic analytical constructs based on Lemke's Semantic Relations for Thematic Analysis (Lemke, 1990, p.221-224). They did not appear in the CLM materials and were not taught to the students, but are indicated in the examples of this article to illustrate the semantic relations in the thematic patterns of the CLM materials.

period. Both the S4 teacher (i.e. Miss T) and the S5 teacher were experienced science teachers qualified to teach biology in English. According to the teachers, the students in S4 and S5 were both well-motivated in learning. However, although their English language proficiency was above-average among same-grade students in the city, their academic language literacy remained insufficient which affected their learning of the content subjects (e.g., biology and geography) in English as an additional language. During the intervention, pre-test and post-test were administered for the two classes on the same day. The number of biology lessons and the length of each lesson were equal for both classes following the school regular schedule, with S4 (i.e. the intervention class) adopting the CLM pedagogy while S5 (i.e. the control class) only participated in the pre/post-tests without trying out the CLM materials or activities.

Table 1. Details of control class and intervention class

	Intervention Class	**Control Class**
Grade	S4 (Grade 10)	S5 (Grade 11)
Number of students	N=28 (gender evenly distributed)	N=30 (gender evenly distributed)
Age	15-16 years old	16-17 years old
L1	Cantonese	Cantonese
English language proficiency	above-average among same-grade students in the city	above-average among same-grade students in the city
Discipline	well-motivated with good learning attitude	well-motivated with good learning attitude
Teacher	experienced Hong Kong local science teacher; female; Cantonese as L1 but qualified in teaching science in English; first time collaboration with the project	experienced Hong Kong local science teacher; female; Cantonese as L1 but qualified in teaching science in English; first time collaboration with the project
Number of lessons during intervention	8 lessons at the same teaching weeks in the school schedule	8 lessons at the same teaching weeks in the school schedule
Pre-/post tests	taken on the same day	taken on the same day
Teaching resources	tried out during intervention	not available

4.2 Data collection and analysis

The concurrent triangulation mixed methods strategy (Creswell, 2003) was used to confirm, cross-validate, or corroborate the findings with both quantitative and qualitative data. A quasi-experimental design was employed to estimate the impact of CLM pedagogy in facilitating students' development of content knowledge and language knowledge. Both the pre-test and post-test examined similar content knowledge from the same unit using the same question types

including multiple-choice questions, blank-filling, short questions, long questions or essay questions. To reduce testing effect, the teacher did not check answers with students after the pre-test. The quantitative data from the pre-test and post-test were collected at the beginning and end of intervention respectively. During the intervention, the researchers observed and videotaped the biology lessons taught using the CLM approach. After the intervention, a 30-minute focus group interview was conducted with five students of different academic achievement levels to probe their feedback on CLM pedagogy; and a semi-structured interview was conducted with the teacher to probe her reflection on the intervention. The quantitative data included the pre-test and post-test scores of the control and intervention classes. The qualitative data consisted of approximately 280 minutes of videos of eight lessons, 75 minutes audio-taped interviews (a 30-minute focus group interview with students and a 45-minute semi-structured interview with Miss T), and pre/post-test papers in both the control and intervention classes. Since different types of data were collected concurrently in one research phase using both quantitative and qualitative approaches, this made it possible for the researchers to offset the weaknesses of one method with the strengths of the other. According to Creswell (2003), the concurrent triangulation mixed methods strategy produces "well-validated and substantiated" findings as it generally integrates the results of both qualitative and quantitative methods during the interpretation phase which "can either note the convergence of the findings as a way to strengthen the knowledge claims of the study or explain any lack of convergence that may result" (p. 217).

The quantitative data were analysed following two steps: First, the pre-test and post-test were scored by a science-major research assistant and two research assistants who had graduated from a MEd CLIL programme. The science-major research assistant scored the content knowledge in the tests according to the answer key checked by both the research team and the participating teachers. The CLIL research assistants scored the language knowledge of

the answers in structured questions or short essays. A marking scheme for language knowledge was designed based on the CLIL practices and principles guided by genre theories of the Sydney School (Rose & Martin, 2012; Lin, 2016); namely, scores were given to correct use of language features at different levels including subject-specific vocabulary, general academic vocabulary, logical connectors, sentence patterns of academic functions, complete sentences and proper text structures. Drawing on the theoretical principle that language and content are always related (Halliday, 1993) and to avoid rote-memorized answers which were linguistically correct but irrelevant to the content topic, only correct language features in test items where the content knowledge question was also correctly answered were scored. The inter-rater correlation for the language knowledge scores was 90%. Second, the pre-test and post-test scores in the control and intervention classes were compared by independent sample *t*-tests to examine whether the CLM approach might have made a significant difference between the two classes. To minimize the confounding effects of the prior differences between the two classes, ANCOVA was performed to compare the post-test scores in the intervention class with those in the control class, using their pre-test scores as the covariate.

The qualitative analysis involved three types of qualitative data to allow for triangulation of different research findings (Creswell, 2003). First, the observed lessons were analysed iteratively focusing on the episodes where the CLM materials were applied. The lessons were transcribed verbatim, and the transcripts were then analysed using the conversation analytic method of sequential analysis (Lin, 2007). Second, to corroborate the researchers' interpretations of the lesson observations, the first author interviewed both the teacher and the students to explore their perceptions and feedback about the CLM pedagogy tried out in their classes. During the interview, the teacher and the students elaborated on how they used the CLM materials which helped the researchers to better understand whether the CLM approach facilitated the students' language and content development and how the teacher

used the CLM resources to guide the students to better understand the biology topics. Third, the researchers' interpretation of both the lesson observation and interview data was corroborated by post-test results and the analysis of the essay question answers produced by students in both the control and intervention classes.

5. Results and Analysis

This section addresses the research questions using both quantitative and qualitative data, which are analysed based on the conceptual framework of the study.

5.1 The CLM approach facilitated content and language development in the EMI biology classroom

The first research question will be addressed by the quantitative data in section 5.1.1 and the qualitative data in section 5.1.2.

5.1.1 Quantitative results

The quantitative data included pre-test and post-test scores. Table 2 and 3 summarized the statistics on content and language knowledge development of both the control and intervention classes.

Table 2. Summary of *t*-test results on content knowledge development

	Control Class		Intervention Class		
	M	SD	M	SD	*t*-test
Pre-test	11.938	2.435	10.250	3.273	0.026*
Post-test	23.650	6.987	30.250	4.906	0.000***

*$p < .05$. ***$p < .001$

Note. M=Mean. SD=Standard Deviation.

Regarding content knowledge development, Table 2 shows that the pre-test mean score of the control class (*n*=32, *M_pre-con*=11.94, *SD*=2.44) is higher than that of the intervention class (*n*=28, *M_pre-int*=10.25, *SD*=3.27); while in the post-test, the mean score of the control class (*n*=30, *M_post-con*=23.65, *SD*=6.99) was lower than that of the intervention class (*n*=28, *M_post-int*=30.25, *SD*=4.91). An independent-samples *t*-test was conducted to determine whether differences existed between the control and intervention classes in their pre-tests and post-tests. The *t*-test results indicate that the difference between the two classes in the pre-test are statistically significant, but the difference is not very large with a *p*-value slightly smaller than .05 (t (58) = 2.28, p =.026 <.05). Whereas in the post-test, the *t*-test results reveal that the difference between the two classes is highly significant with a *p*-value smaller than .001(t (52) = -4.19, p =.000 <.001). After eliminating confounding effects of the pre-tests, an ANCOVA showed a strong effect of group difference: F (1, 54) = 26.08, p =.000 <.001, η_p^2 = 0.33.

Table 3. Summary of *t*-test results on language knowledge development

	Control Class		Intervention Class		
	M	SD	M	SD	*t*-test
Pre-test	2.781	1.237	3.107	1.771	0.408
Post-test	16.667	6.307	27.786	6.754	0.000***

*p< .05. ***p< .001

Note. M=Mean. SD=Standard Deviation.

Concerning language knowledge development, Table 3 shows that the pre-test mean score of the control class (*n*=32, *M_pre-con*=2.78, *SD*=1.24) is lower than that of the intervention class (*n*=28, *M_pre-int*=3.11, *SD*=1.77); while in the post-test, the mean score of the control class (*n*=30, *M_post-con*=16.67, *SD*=6.31) is still lower than that of the intervention class (*n*=28, *M_post-int*=27.79, *SD*=6.75). An independent samples *t*-test was run to decide whether differences exist between the control and intervention classes in their pre- and post-test scores. While the *t*-test results indicate that the difference between the two classes was not statistically significant in the pre-test, with a *p*-value larger than .05 (t (58) = -.83, p=.41 >.05); in the post-

test, the difference between the two classes was highly significant with a *p*-value smaller than .001(t (56) =-6.48, p=.000 <.001). After removing the confounding factor of pre-test, the ANCOVA result revealed a strong effect of group difference, F (1, 54) = 39.27, p =.000 <.001, $\eta_p^2 = 0.42$, with very strong observed power at 1.00. These results indicate that the intervention is highly likely to have had a positive impact on students' content and language development.

5.1.2 Qualitative results

The quantitative results were corroborated by the qualitative data. The interviews with both the teacher and students about their feedback to the CLM approach turned out to be positive. As shown in Appendix 1, the students found the CLM materials *"helpful", "useful", "beneficial", "good", "better than the textbook notes", "simple and clear", "make learning easy"*, "*help me learn*", and "*help me better understand the words*"; they also found the C+L activity---a concept guessing game, "*fun and engaging*". According to the students, the reasons behind the positive comments included: first, the "*key words*" (i.e. the thematic items in the thematic patterns) in all materials were "*bold*" (subject-specific vocabulary as MEDIUM, AGENT or TARGET), "*underlined*" (the key verbs as PROCESS) and "*bold and italic*" (logical connectors) so that the students kept focusing on the thematic patterns and semantic relations in the materials; second, the C+L cards and maps summarized the *"key points*" in "*complete sentences*" introducing "*entire points*" and "*whole processes*" so that the materials "*included all relevant concepts*" and the relations among the concepts were "*simple and clear*" which allowed the students to retrieve information from a "*more focused*" knowledge domain without "*skipping the points*"; third, the sentence-making tables highlighted the main functions and logical relations (e.g., defining, expressing cause and effect) which helped the students understand the meaning of the thematic items and the interrelations within/between the

thematic patterns; fourth, rather than providing only verbal notes, the CLM materials contained multimodal information (e.g. diagrams and arrows) which enabled students to "*visualize the concepts*" more easily; fifth, the CLM material-based questions-and-answers during the lessons made the content knowledge "*more impressive*"; and sixth, the CLM materials enhanced students' language knowledge including spelling, pronunciation, and the uses of every day and academic vocabulary. Students longed for more CLM materials in future lessons which they would use for distinguishing and memorizing concepts and making notes during self-directed learning.

Just like the students, Miss T also had favourable feedback on the CLM materials. She commented that the students had mastered the lesson "*quite well*" even though it was an abstract unit, and ascribed this to the CLM materials which "*included all key concepts ranging from simple to complex*". Miss T found the C+L cards "*very clear*", "*including all key points*" but appear "*more focused*". She summarised three points of the C+L maps which she "*appreciated*". First, since diagrams were presented next to the corresponding concepts, they enabled students to "*visualize*" the abstract concepts easily. Second, the interrelatedness of visual and verbal information not only helped students understand the meaning of the concept but also reminded them of its structural representation. Compared with the bullet-point summaries in textbooks, Miss T thought the C+L maps are more helpful because their multimodal features "*give students more ideas*"; more importantly, the CLM materials encouraged students to learn concepts and the interrelationship between concepts by meaningful learning rather than "*rote learning*". A third feature of C+L maps which Miss T described as "*really good*" is the sequencing function. With the C+L maps presented via PowerPoint, the different concepts and the interrelations between concepts were not shown all at once in a huge fixed map, but appeared one by one according to the growing complexity of the concepts, which "*helped students learn the logic*" not only about how concepts in different

C+L cards were linked, but also how different concept networks in different C+L maps were interconnected. Such sequencing which enabled teacher-student co-construction of concept meaning was also appreciated by students, such as S5, who said "*it really makes learning easier because the concepts can be put one by one back into the C+L Map".* As for the sentence-making tables and essay writing guides (Figure 3), Miss T was sure that both materials helped "*raise students' language awareness*". According to the teacher, due to the lack of academic writing skills, students tended to rote-learn the bullet-point notes in the textbook without paying attention to science literacy or academic language literacy. The two types of CLM materials raised students' awareness about the logical relationships in the texts, the need to elaborate on arguments, and the use of subject-specific and general academic vocabulary in academic writing.

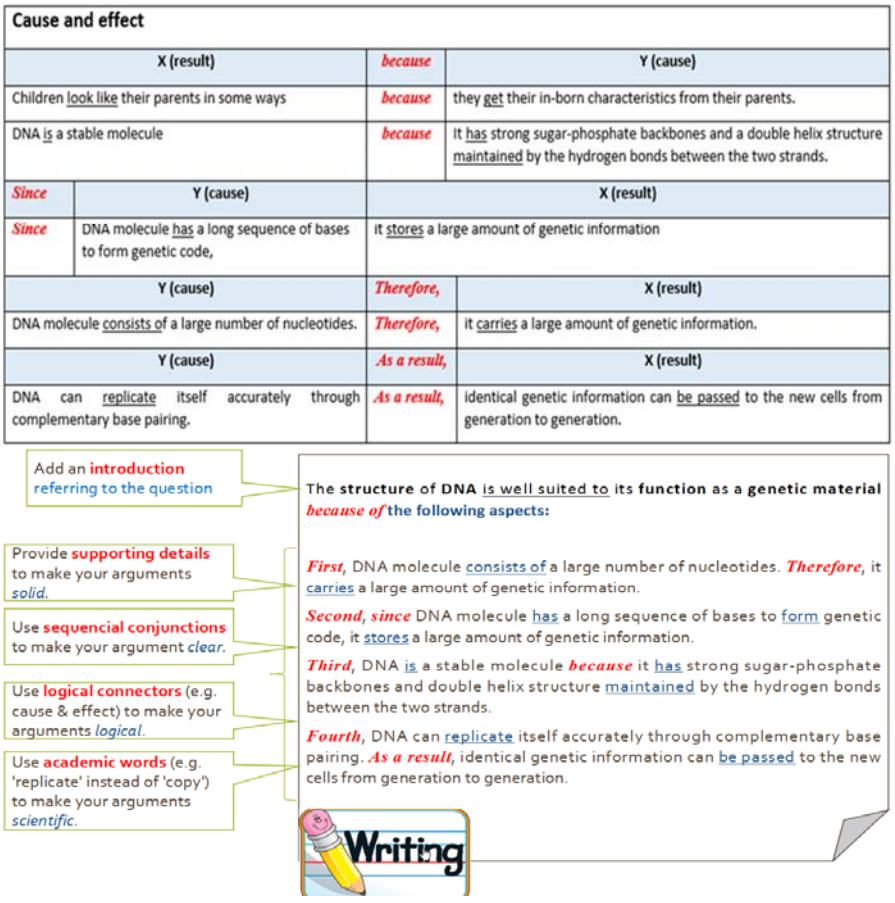


Figure 3: A sentence-making table and an essay writing guide

We shall further discuss these in the next section where qualitative data from class observations will be analysed to explore how the CLM approach facilitated content and language knowledge development in the EMI biology classroom.

5.2 Integrating content and language learning with thematic-pattern-based designed and spontaneous scaffoldings in shifting communicative approaches

Before Miss T's lessons, the CLM materials were distributed to the students. They served as designed scaffolding which provided the teacher and students with shared materials to do both self-directed and collaborative learning.

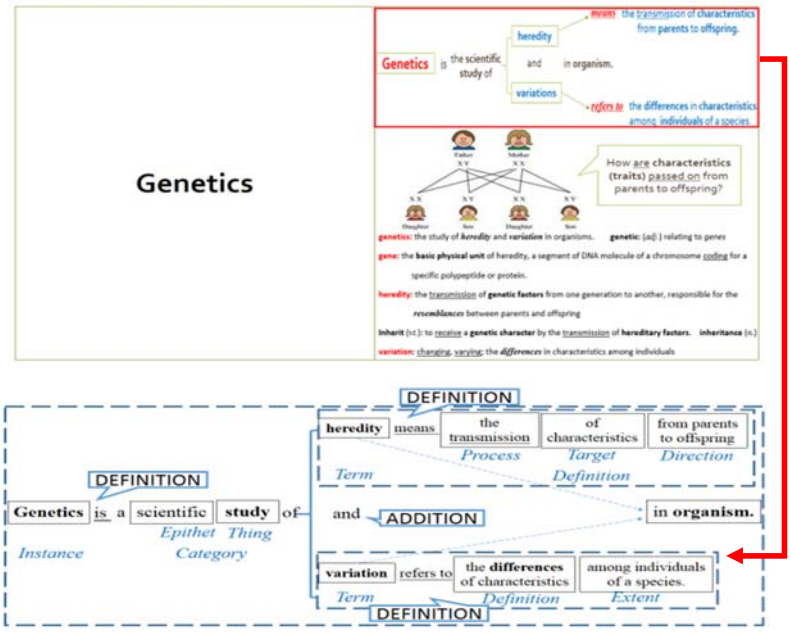


Figure 4: C+L card "genetics" and the thematic patterns of its definition

For example, when learning the concept "genetics", students were able to identify the definitions of the three interrelated concepts in the C+L card (Figure 4). Thus, instead of just noticing the definition of "genetics", students learned simultaneously the interrelationships embedded in the thematic pattern of this highly condensed concept (i.e. "genetics") which guided them to further de-construct the more detailed thematic items and interrelated semantic relations of its two basic thematic items (i.e., "heredity" and "variation") in their own

corresponding thematic patterns. The C+L cards as designed scaffolding were a useful self-directed learning tool not only during the lessons but also after school.

5.2.1 Multimodal animated sequential "Concept + Language Mapping" with thematic-pattern-based designed and spontaneous scaffoldings

With key concepts taught, the teacher guided students to build up interconnection between different concepts by using a C+L map which was converted to a blank-filling worksheet (Figure 5) so that students could recap concepts and discuss them with peers.

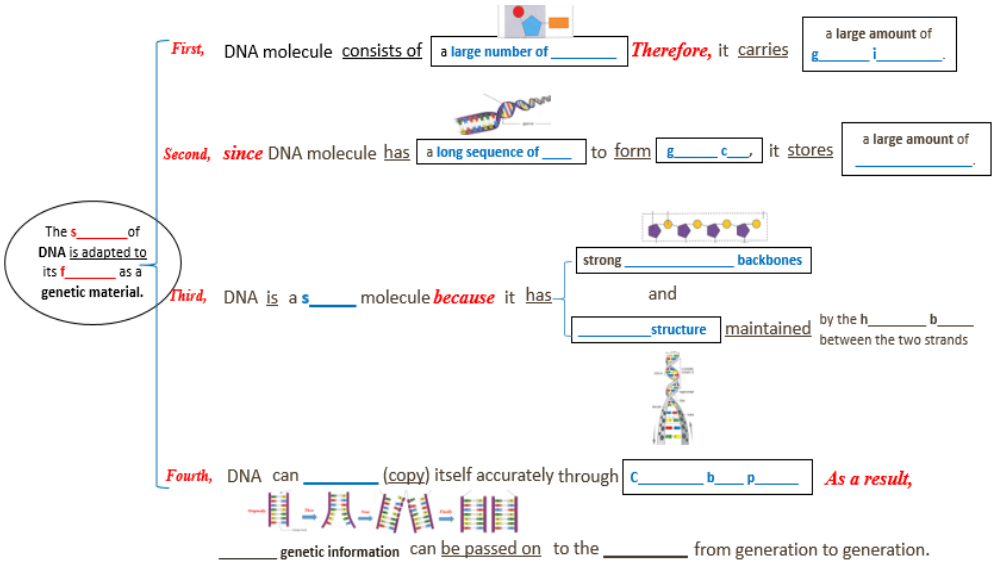
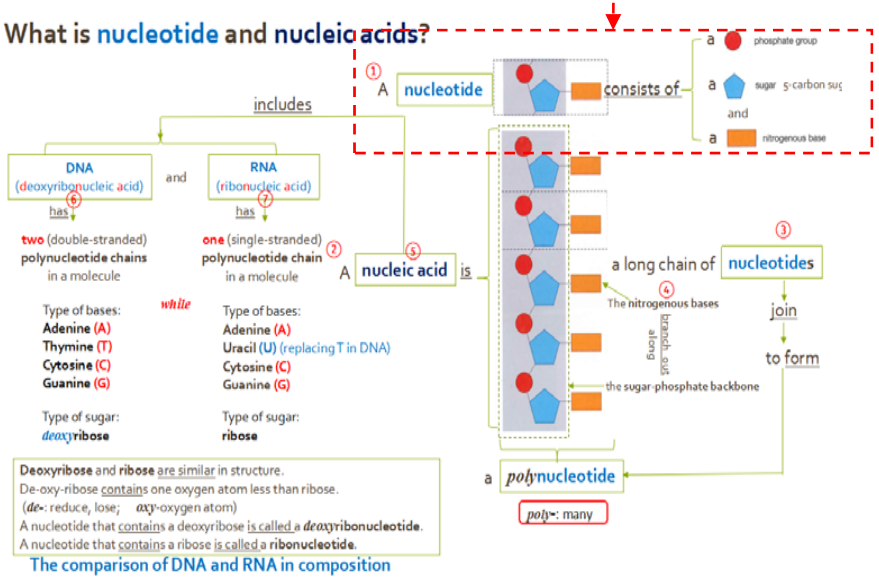


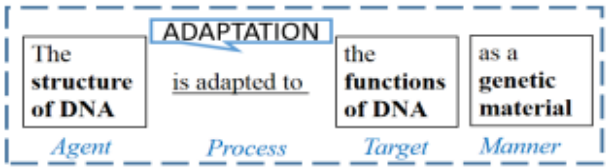
Figure 5: Blank-filling C+L map "DNA structures and function as a genetic material"

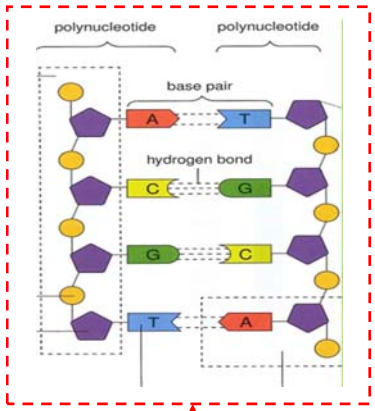
The students searched their CLM materials for answers to the C+L map worksheet. After completing the exercise by themselves, they discussed in groups. During discussion, they compared answers, questioning each other and justifying their own answers by showing evidence from the CLM materials or the textbook. According to Miss T, the peer discussion, as an "interactive/dialogic" communication approach (Mortimer & Scott, 2003) was necessary as it offered students opportunities to review the concepts, negotiate understandings, explore

new ideas and correct misconceptions about the lesson. The C+L map worksheet and the other CLM materials as designed scaffolding thus became useful artifacts and references facilitating collaborative learning during class.

As the C+L map summary was composed of different themes and thematic patterns linked from different parts of the textbook, it formed a thematic nexus (Lemke, 1990) --- a global network of meaning relationships with patterns of thematic items interconnected and further embedded in more complex patterns of semantic relationships. For example, Figure 6 illustrates thematic patterns and thematic items that co-construct the thematic nexus and semantic relationships within the global thematic pattern. The thematic topic "The structure of DNA is adapted to its function as a genetic material" was a thematic nexus composed of four themes, each of which consisted of a "cause and consequence" relationship with the "cause" and "consequence" both constituted by thematic patterns of interconnected thematic items. Each thematic item itself was highly condensed which could be further unpacked into thematic items and semantic relations of its own. For instance, the thematic items "nucleotide" and "complementary base paring" both have their own thematic patterns which had been shown in different C+L maps (i.e. "What is nucleotide and nucleic acids?" and "What is DNA?") elaborated in the previous lessons. With such a huge thematic web woven by complex semantic relationships as well as abstract and highly condensed thematic items, the blank-filling C+L map as a summary of the lessons could be very difficult for some of the students. The CLM materials (cards and maps) as well as the summary worksheet turned out to be useful designed scaffolding for self-directed revision and inquiry of the lesson, and the interactive/dialogic peer discussions were also beneficial collaborative learning activities.







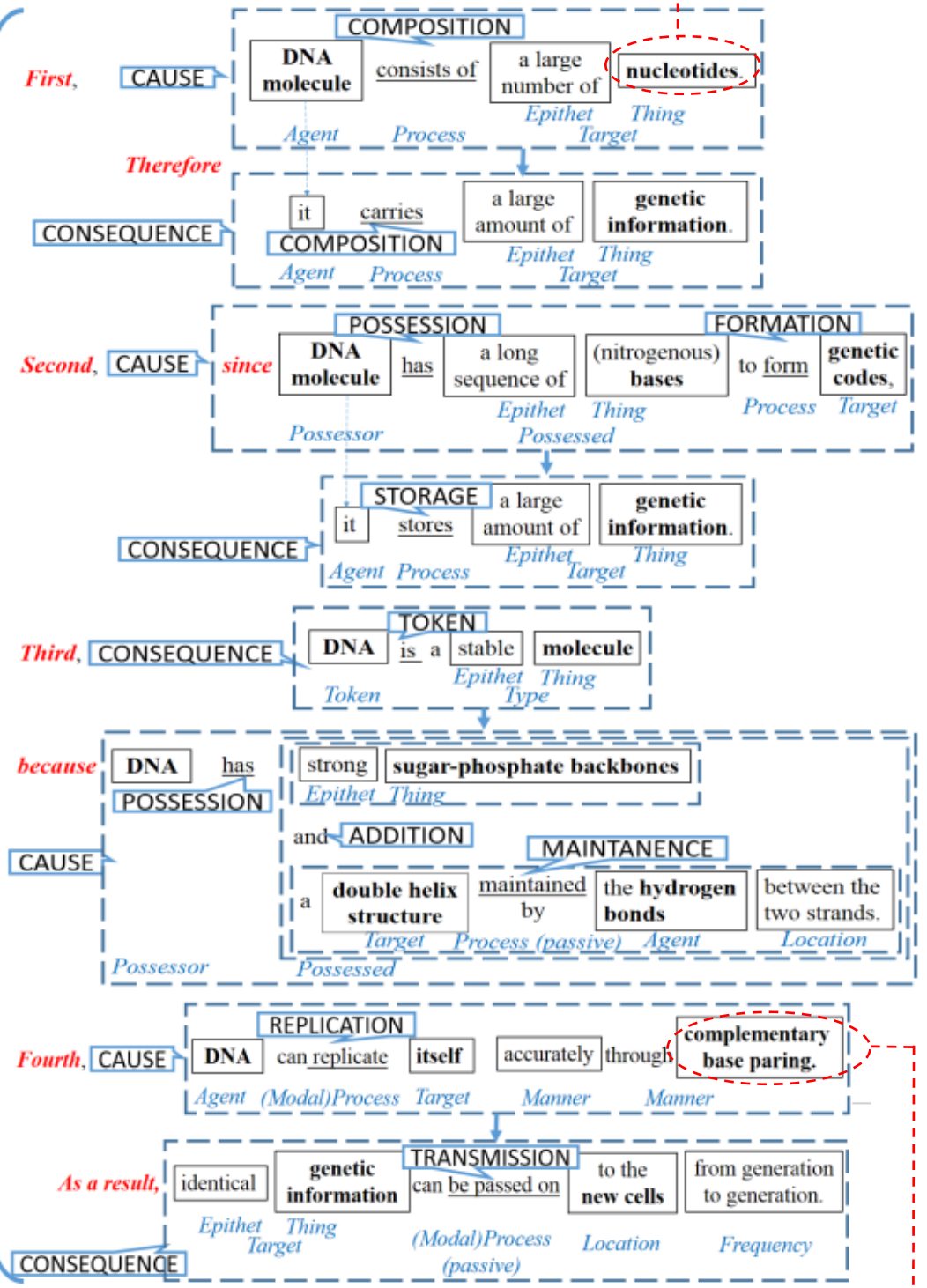


Figure 6: Thematic patterns, thematic nexus, and semantic relationships

It should be noted that the highly abstract biology lesson was not only facilitated by the CLM materials as designed scaffolding but also by the thematic-pattern-based spontaneous scaffolding (Gibbons, 2009; Lin, 2016) provided by the teacher during classroom interactions. Though by self-directed learning and peer discussion students were able to complete the C+L map worksheet, they needed to verify their thinking through further negotiation with the teacher by co-constructing the C+L map in a series of teacher-student triadic dialogues (Lemke, 1990). Such triadic dialogues were orchestrated with multimodal "C+L Mapping" facilitated by the special design of the C+L map on a PowerPoint slide. To allow the teacher and students to jointly construct the C+L map, the concepts in the map did not appear on the slide all at once, but was shown item by item according to the sequence in which the thematic patterns were discussed. This enabled both the teacher and students to focus on the same thematic pattern. The C+L map became bigger and increasingly complex as more thematic items were identified and more thematic-patterns explained, and such sequence of discussion about the themes, according to Miss T, fits with the strategy of *"from simple to complex*". The questioning was based on the thematic patterns in each theme. During co-construction of the C+L map, Miss T did not just probe students for answers to the missing item of a particular thematic pattern in the blank-filling C+L map, she also asked students to define the thematic item by identifying its own condensed thematic pattern and corresponding thematic items. For example, in one scenario, after EV provided the answer "*a large number of nucleotides*", Miss T asked students to further elaborate on the composition of nucleotide which could be prompted by the diagrams next to the concept in the C+L map. According to Miss T, the diagrams in the C+L map "*really helped students think"* because *"when students read the diagram several times, they know what concepts the diagrams represent"*. Thus, apart from asking students to recap the basic components of the structure of "nucleotide", she also reminded them to focus on

the details of the corresponding diagram so that *"they also know the structure of the concepts and are able to draw them out"*.

The "interactive/authoritative" communication (Mortimer and Scott, 2003) guided by Miss T was also crucial as there were students who could not fully understand at once the thematic patterns in the complicated C+L map, hence needed spontaneous scaffolding from the teacher to help them clarify the concepts. In the following teacher-student interaction, Miss T guided MG to figure out the thematic item "nitrogenous base" in the C+L map.

T *Second. What will be the answer? MG*
MG *Second, since DNA molecule has a long sequence of nucleotide…*
T *Ah… DNA molecule has a long sequence of nucleotides. We know that it contains a sequence of…*
MG [correcting himself] *A long sequence of genes.*
T *A long sequence of genes. But what? Which part in the genes to form the…*
MG *Chromosome.*
T *Form the chromosome? No… The DNA molecule has a long sequence of which structure to form the …*
MG *Form the* ***genetic code****.*
T *Form the genetic code. Very good. But which part of the nucleotide? Which part of the nucleotide form the genetic code? This is the point. The phosphate group? Or the…*
MG ***Nitrogenous base.***
T *Nitrogenous base. Very good. Here you will find that DNA molecule has a long sequence of …*
MG *Nitrogenous base.*
T *Nitrogenous bases, or a long sequence of bases to form …*
MG *Form the genetic code.*
T *To form genetic code.*

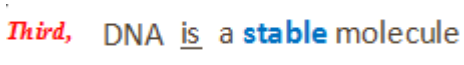
Excerpt 1: Thematic-pattern-based spontaneous scaffolding in interactive/authoritative communication

From the guiding questions, the revision of the structure of nucleotide during the discussion of the previous theme turned out to be important. As Miss T and KG had just recapped the components about the structure of nucleotide, MG could remember the structure clearly; hence, when the teacher provided the spontaneous scaffolding as a prompt ("*But which part of the nucleotide? Which part of the nucleotide form the genetic code? This is the point. The phosphate group? Or the…*"), he could utter the answer "nitrogenous base" at once and then went on jointly constructing the rest of the theme with the teacher.

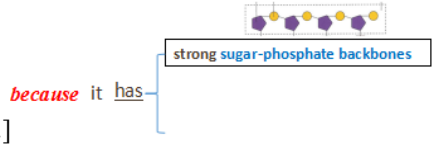
5.2.2 Integrating content and language by combining thematic patterns and genre structures

Apart from providing designed and spontaneous scaffoldings to help students understand the thematic patterns and semantic relationships, the teacher also reminded students of the language knowledge which is inseparable from meaning making of the content knowledge. For example, during answer-checking, a student mixed up "*stable*" and "*strong*" when describing the characteristics of the DNA molecule. Miss T helped him select the appropriate modifier by providing spontaneous scaffolding about the thematic pattern.

T *How about the third sentence? How about the third sentence? LG. How about the third sentence? Third.*
LG *DNA is a strong molecule because…*
T *Is a … What molecule?*
LG *Strong.*
T *Is a strong molecule? You use strong here? Um? YY, would you help him?*
YY *DNA is a **stable** molecule.*

[T showing the third characteristic on the screen.] 

T *Is a stable molecule. Stable is better than strong here. Okay. You can say that the bonding is very strong. The covalent bond is very strong but the hydrogen bond is relatively weaker. Okay. But we won't say that the molecule is strong. The molecule is stable. YY. Sit down please.* [Turning to LG again and ask another question.] *Why the DNA molecule is stable?*
LG *Because it has strong **sugar-phosphate** backbones.*



[T showing the words about the reason on the screen.]
T *Good! It has strong sugar-phosphate backbones.*

Excerpt 2: Content and language integration based on thematic patterns

In this example, the collocations of the two adjectives (EPITHET: stable and strong) with the corresponding nouns (THING: molecule and backbone) were related to the specific characteristic of the DNA structure and its function which implied a cause and consequence relationship; i.e. DNA is a *stable* molecule because it has *strong* sugar-phosphate backbones and a double-helix structure. The students needed to understand the semantic relationship in the thematic pattern to decide the proper modifier. Hence, it was necessary for the teacher to supplement this spontaneous

scaffolding about the relationship between thematic patterns and language features to help students clarify the proper collocations between modifiers and things in the thematic patterns which enabled them to understand the characteristic of DNA accurately.

During teacher-student interactions, spontaneous scaffolding on language knowledge were also provided intermittently. For example, when discussing the first theme, Miss T asked students to use the synonyms "consists of", "contain" and "has" when they expressed the meaning of composition which appeared repeatedly in the C+L map. Similar examples also included the paraphrasing of "passed on" and "transmit" which she encouraged students to associate the learned vocabulary (e.g. transmission) with the newly appear ones (e.g. pass on). When the teacher elaborated on the key concept "complementary base pairing", she asked a student to use an example from the content knowledge to explain "complementary" (*"What does complementary mean? Would you give us an example? If the base is A, it should pair with…?").* By doing so, Miss T conveyed to students a message that language use was closely associated with the meaning network---thematic patterns of the science lesson. She also reminded students to use academic vocabulary (e.g. replicate) to replace the everyday words (e.g. copy) when answering essay questions which was a typical weakness of the students in high-stake exams.

6. Discussion

The research findings indicated that the thematic-pattern-based CLM approach facilitated both content and language knowledge development in the EMI biology class. Data analysis revealed that concept and language mapping was a process of integrating content and language by intertwining thematic-pattern-based (Lemke, 1990) designed and spontaneous scaffoldings (Gibbons, 2009; Lin, 2016) in dialogic/authoritative interactions (Mortimer & Scott, 2003). The

CLM pedagogy started with the design of CLM materials and activities according to the thematic topic of the content subject. The thematic patterns and semantic relationships were represented by the multimodal animated CLM materials in forms of C+L cards, C+L maps, sentence-making tables and essay writing guides which were circulated in the EMI biology lessons through a series of talking, reading, writing, representing and doing communication activities (Osborne, 2014) in the "repetition with variation" strategy (Lemke, 1990).

The CLM materials as designed scaffolding make science learning more "*focused*" and "*complete*" by condensing and weaving thematic relations into thematic nexus. What make the CLM pedagogy more "*flexible*" and "*impressive*" are the multimodal (e.g. the diagrams besides the corresponding thematic items in C+L cards/maps), animated (e.g. the dynamic emerging of thematic items one by one to keep teaching and learning at the same pace) and sequential (e.g. the "*from simple to complex*" arrangement of thematic patterns) design of the C+L maps on the PowerPoint slides. All these "properties" are best orchestrated through the spontaneous scaffolding of the teacher who guides the joint construction of the science story through a series of triadic dialogues based on not only the thematic patterns of the science lesson but also the academic language features in the science texts. Following the "repetition with variation" principle, the thematic patterns about the same thematic topic which are explicitly introduced in the same lesson or implicitly related to previous lessons will be connected, talked about, and further explored through a series of C+L activities. It should be noted that, in EMI CLIL context where the content subject is taught in an additional language of the students (teachers), the combination of thematic patterns and rhetorical/genre structures is equally crucial for effective science teaching.

6.1 Integrating content and language in CLIL lessons

Previous studies exploring CLIL have accentuated the integration between content and language as the "core concept" (Lorenzo, 2016). Morton and Llinares (2017) emphasized the need to clarify the "actual meaning of the label" (i.e. integration) pointing out the phenomenon that "...the term (CLIL) seems to be mainly used to describe bilingual education context where content classes are taught through an additional language but where little integration of content and language happens" (p.2). Lyster (2007) proposed the counterbalanced approach, but called for further research on the link between the subject-matter class and the English-as-foreign-language class. Lin (2016) also stressed that a well-developed framework for description of language patterns is available (e.g. the Genre-Egg framework based on the Sydney School of genre theories), "however, for the precise description of content, we still need to develop a theoretical framework to enable us to describe units of meaning in specific content areas" (p.179).

The thematic-pattern-based CLM pedagogy proposed in this study to some extent achieved the effect of content and language integration. As Lemke (1990) clarified, "Talking Science' does not mean simply talking about science; it means doing science through the medium of language" (Abstract of *Talking Science*). According to Lemke, students should be taught both the thematic patterns and the genre of science because reasoning is based on both the use of thematic patterns and genre structure patterns, the former supplies the content and the latter supplies the form of organization of the argument. As can be seen from the data analysis, the CLIL lessons in the CLM approach cannot separate content and language, as the thematic patterns (i.e. "a network of relationships among the scientific concepts in a field, but described semantically, in terms of how language is used in that field" (Lemke, 1990, p.12)) in forms of CLM materials and activities linked up every teaching stage of the CLIL lessons with thematic-pattern-based designed

scaffolding and spontaneous scaffolding facilitating the talking, reading, representing, writing and doing science in the CLIL classroom.

6.2 Drawing on perspectives of subject education researchers

Echoing Halliday's (1993) point that content and language are always integrated, researchers and educators in subject education also base their work on the premise that "learning the language of science is a major part (if not the major part) of science education. Every science lesson is a language lesson" (Wellington & Osborne, 2001, p.2). In this study, not only do science experts provide us with important theoretical implications (e.g., thematic patterns theory by Lemke, 1990; concept mapping by Novak et al. 1983; and the review of scientific practices and inquiry by Osborne, 2014), they also propose useful pedagogical strategies and techniques from their research findings. For example, the design of multimodal animated C+L materials has adopted the research designs of subject education researchers such as Cheng and Gilbert (2015) and Nesbit and Adesope (2011). The feedback of the teacher and students as well as the lesson observation findings also proved that the pedagogical techniques proposed by the subject experts were important scaffoldings for CLIL lessons.

6.3 Teacher education about "thematic-pattern-based" CLM pedagogy

The thematic-pattern-based CLM approach being a newly developed pedagogy, its feasibility, practicality and sustainability need to be carefully discussed and reflected on. Judging by the background of the EMI curriculum in secondary education in Hong Kong and many other regions and countries where content subjects are taught in an additional language of the students (and the

teachers), the CLM approach may contribute to CLIL practices by providing a potentially feasible pedagogy and research-based references. However, it should be noted that, under exam-oriented school culture, there may be challenges in adapting this new pedagogy to EMI classrooms. Some students have become so accustomed to rote learning that they may find the CLM materials contain "not enough words" for them to memorise directly; for example, one student explained that she recited all notes word by word because she would learn science subjects as if she was learning Chinese History, a subject which students believed involves considerable amount of memorization. Although the majority of students had positive feedback on the CLM pedagogy, some of them worried about the limit of lesson time, as one commented, on one hand the teacher's step by step guidance based on the C+L maps as well as her questioning following the animated sequencing of the different bits of information helped him to learn the concepts better with clearer understanding; on the other hand he also thought the pedagogy time consuming as the teacher could just give students the answers and ask them to check the worksheet themselves. To address these challenges, teachers adopting the CLM approach need to emphasise two principles: first, rather than learning by rote memorization, the pedagogy encourages learning by meaning making; namely, to help students to integrate content and language learning through understanding the semantic relationships within and between the thematic patterns of content subjects; second, the pedagogy does not just provide CLM materials as designed scaffolding, more importantly, it accentuates the spontaneous scaffolding (Gibbons, 2009; Lin, 2016)---the teacher's step by step deployment of the "concept + language mapping" materials and activities as well as the classroom interactions during which the teacher guides the students to achieve thematic coherence (Bloome, Carter, Christian, Otto, & Shuart-Faris, 2005) of the CLIL lessons.

Another key issue regarding teacher education will be the teacher knowledge about the CLM approach. Morton (2018) re-conceptualized CLIL teacher knowledge and proposed the construct of "language knowledge for content teaching" with two sub-domains: common language knowledge for content teaching and specialized language knowledge for content teaching. The thematic-pattern-based CLM approach demands not only teacher language knowledge and content knowledge, but how the two types of knowledge may be integrated according to the CLIL lesson. It would be unrealistic for teachers to self-learn the theory and develop the CLM materials all at once as they may feel too abstract to fully understand the theory only by self-directed learning. The "Collaborative, Dynamic and Dialogic Process" CLIL teacher education model (He & Lin, 2018) may be one of the solutions. Teachers may join Master of Education programmes in the field of CLIL or sharing sessions of CLIL teacher professional development workshops to learn about the theory and skills relevant to the CLM pedagogy and then try out part of the CLIL lessons by collaborating with colleagues in the school.

7. Conclusion

In this study, we developed a thematic-pattern-based CLM approach and tried it out in an EMI biology classroom. Both quantitative and qualitative data indicated that the CLM approach had a positive effect on students' development of both content and language knowledge. However, it should be noted that the present study adopted a quasi-experimental design but there was only one intervention class and one control class with around 30 students in each cohort. The limit of class number and class size may affect the quantitative result of the study. Future research on thematic-pattern-based CLM approach may need to increase the number of classes and adopt a longitudinal research design. Intervention may be tried out in other subjects with medium of instruction other

than English. Data collection may also include students' design and elaboration on their own CLM materials, e.g. how students express their understanding of the thematic patterns through their own C+L maps. Data analysis may focus on the effects of interactive/dialogic communications on students' content and language development.

Judging by the shortage of evidence-based research on CLIL and the difficulties that CLIL teachers have encountered (e.g. lack of pedagogical support and CLIL teacher education, tight teaching schedule, heavy workload, pressure of high-stake exams, etc.), we recommend more support for the research of CLIL education and CLIL teacher professional development (He & Lin, 2018). The thematic-pattern-based CLM pedagogy, research methods as well as research findings of this study may be useful resources upon which further investigation can be developed.

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Appendix 1. Summary of student feedback on the CLM materials

	C+L cards
S1	*I use the C+L cards to help me memorize the concepts... Because Miss T used to end a unit very quickly, to understand the lessons better, we need to highlight the key points by ourselves and then read them several times after class. In fact, many key points are already there (in the C+L cards) and we simply glance at the cards and get the idea of the concepts...I think they (C+L cards) are quite helpful. Actually, sometimes, even though I'll highlight the key points myself, I would miss some or just skip them directly.*
S2	*I think it'll be much better if we have the C+L cards, because, frankly speaking, textbooks usually have many useless words, I mean, words that are not so relevant. The C+L cards help us summarize all key points without any nonsense.*
S5	*I find the notes in the C+L cards helpful for me, because I also make notes myself, and I used to make notes in point forms. Comparing the C+L card notes with mine, now I'll make them more detailed; like, I'll add some pictures and diagrams to make them more impressive.*
S2	*I think the C+L cards are better (than the bullet point notes in the textbook) because their ideas are in complete sentences showing an entire point in a whole process; but the textbook bullet points only mention the key parts without telling what happened before and what will come next.*
S3	*Yeah, I like them (diagrams, arrows and boxes on the C+L cards), because sometimes if I just read the text, it'll be too hard for me to imagine the concepts at once, but if the diagrams are shown, I can visualize the concepts right away. For example, if the diagram of a cell's epithelium is shown, I can think of its functions at once.*
Ss	**R:** *When doing exercises, will you take out the corresponding C+L cards to see, for example, what are "recessive" and "dominant", and how to distinguish "heterozygous" and "homozygous"? Will you?* **Ss:** *Yes.*
	C+L maps
S5	*I noticed that some words are deliberately bold and some underlined (in the C+L maps) ... I'll pay particular attention to these words, and I think it really makes learning easier because the concepts can be put one by one back into the C+L Map.*
S1	**R:** *Miss T raises questions (about the concepts in the C+L map), students look up answers from the C+L cards, textbook and handouts, and then the teacher goes on elaborating on concepts in the next layer. Is it good to follow such a way to help you consolidate your knowledge?* **S1:** *There are pros and cons.* **R:** *Oh, why?* **S1:** *The cons is that it slows down the teaching, we should have remembered what the answer is as the teacher has just explained it. But for the pros, it makes learning more impressive, because the teacher raises a question (about a concept) and we think about it and then answer the question (with the help of the C+L materials). Such Qs and As help us understand the concepts better.*
Ss **S2**	**R:** *If we collaborate with Miss T again, is it good to design more such C+L maps?* **Ss:** *Yes.* **S2:** *Because they're simple and easy to understand.*
	Sentence-making tables
S4	*I find them (sentence-making tables) quite useful, because we've learned more verbs, especially some subject-specific ones which are must-use words in the unit. So I think it makes things easy.*
S3	*I think they (sentence-making tables) are quite good, because, for example, the cause and effect relation, everything has its cause and effect, the tables illustrate this very clearly. They also have some subject-specific terms, like "replicate", it can't be replaced by "copy". The tables highlight these clearly so that we can learn them well.*
Ss	**R:** *If you are doing a test, such as an essay question, do you know how to use the sentence patterns in the sentence-making tables to answer the questions?* **Ss:** *(Nodding showing understanding)*
S5	*I find the sentence-making tables helpful, because, like this one, you can see the definition at once, just like what you said, there is a pattern telling you (how to use it).*

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