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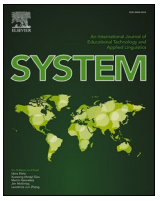

Tracking the development of logical metaphor usage in argumentative writing: A longitudinal study with EFL learners

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ABSTRACT

This study investigated the longitudinal changes in Chinese EFL learners' deployment of logical metaphors in argumentative writing resulting from a one-semester academic writing instruction. Twenty-two undergraduate students participated and completed five argumentative writing tasks. Using systemic functional linguistics (SFL) as a framework, we analyzed data in terms of frequencies and wordings of four subtypes of logical metaphors, namely *cause as verb*, *cause as preposition*, *cause as noun*, and *cause as adjective*. Results revealed a significant increase in students' use of logical metaphors over the semester, especially *cause as verb*. When comparing texts of various grades, stark differences were detected in the quantity as well as the quality of logical metaphors that students deployed. Specifically, higher-scored texts demonstrated a greater and more appropriate use of logical metaphors, particularly in the subtype of *cause as verb*, compared to lower-scored texts. Our findings provide evidence for the effectiveness of academic writing instruction in facilitating EFL learners' deployment of logical metaphors for conveying logical reasoning in argumentative writing. The study highlights the value of logical metaphor analysis in tracking the longitudinal development of L2 academic literacy. It also has some pedagogical implications for successful L2 academic writing.

1. Introduction

Entering into tertiary education, students learning English as a foreign language (EFL) are faced with the need to master argumentative writing (Crosthwaite & Jiang, 2017; Huang & Zhang, 2020; Lee & Deakin, 2016; Zhang & Zhang, 2023). For many EFL students, constructing persuasive argumentation is a challenging task, demanding not only essential knowledge but also the skills to manage linguistic resources to build logical reasoning in the academic discourse (Hyland, 2016; Nesi & Gardner, 2006; Wingate, 2012). In the EFL context of the present study (China), many universities offer compulsory English writing courses for undergraduate students. These courses are designed to enhance students' logical thinking skills and their ability to engage in academic argumentation (Teng & Zhang, 2020; Wang & Huang, 2022; Xu et al., 2023). Within this educational context, a longstanding writing research area is to explore the effectiveness of writing instruction on students' writing performance (e.g., Liu & Furneaux, 2014; Taguchi et al., 2013; Man & Chau, 2019; Teng & Zhang, 2020; Zhang et al., 2023). One specific research area focuses on students' use of grammatical metaphors (hereafter, GM) in academic writing following writing instruction (Hu & Perez, 2022; Liardét, 2018; Liardét & Black, 2020;

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Ryshina-Pankova, 2010). This emphasis on GM arises from its recognition as a potent linguistic resource for construing academic language. It can facilitate the shift from informal toward formal written language by reformulating grammar (Halliday, 1985, 1994; Liardét, 2013; Martin, 1992). Among the various subtypes of GM, logical metaphors are especially crucial, as they serve a pivotal role in guiding readers to grasp the cause-and-effect relationships underpin the author's reasoning, enhancing the coherence within and between the sentences, and contributing to the persuasiveness of arguments (Liardét, 2013; Ryshina-Pankova, 2010).

Despite the evident importance of logical metaphors for building coherence and reasoning in academic writing, there remains a lack of classroom-based research examining whether and how writing instruction facilitates EFL students' use of these devices. Besides, empirical studies have rarely ventured into exploring the longitudinal developmental features of students' deployment of logical metaphors in academic writing. Addressing this gap would deepen our understanding of the effectiveness of writing instruction on EFL students' academic literacy and allow us to capture the dynamic nature of EFL students' linguistic development. Therefore, this longitudinal study aims to explore the changes in EFL students' deployment of logical metaphors across one-semester writing instruction. Based on the longitudinal student dataset, we also intended to analyze differences in logical metaphor use across essays of varying quality and identify the distinctive features of logical metaphors involved in successful argumentative writing. These explorations would offer pedagogical implications for how teachers can better equip EFL students with skills for academic writing success.

2. Logical metaphors in argumentative writing

Rooted in the systemic functional linguistics (SFL) that views language as a social semiotic, grammatical metaphor (GM) is a powerful resource for the realization of potential meanings between the semantics and the lexicogrammar (Halliday, 1985; Halliday & Martin, 1993; Halliday & Matthiessen, 2004; Martin & Rose, 2007). It functions to foreground meaning in nominal expressions, background authoritative or subjective voices, as well as build text cohesion simultaneously, which is thus regarded as a key contributor to academic literacy success and development for both native and non-native writers (Liardét, 2013, 2018; Schleppegrell, 2004).

GM in the SFL sense includes *ideational metaphor* and *interpersonal metaphor* (Martin, 1992). Ideational metaphor is the incongruent way to construe human experience and express meanings of the world, which can be further categorized into two types: *experiential metaphor* and *logical metaphor*. Experiential meanings are concerned with content or information about experience, including participants, process, circumstance, and quality, while logical meanings are concerned with the logical relations of information inside clauses (Devrim, 2015; Martin & Rose, 2007; Ryshina-Pankova, 2015). As illustrated in Fig. 1, in a congruent way of ideational meaning-making, participants are realised by nominal expressions, process verbs, quality adjectives, circumstances prepositional or adverbial phrases, and logical relations conjunctions (Liardét, 2013).

However, language users may construe ideational meanings unnaturally or incongruently, where the semantics and the lexicogrammar are in tension with alternative realizations, involving "a transference of meaning" (Martin & Rose, 2007, p. 110). For instance, instead of being realised by conjunction, logical relations as the focus of this study could be incongruently realised by nominal expressions, verbs, prepositional phrases or adjectives, as shown in Fig. 2. This means that in order to build logical relations, clauses are congruently connected through the Relator, i.e., the conjunctions, positioned between them. However, the logical relations can be construed incongruently to form a single metaphorical clause through a verbal group, a nominal group, adjectives or prepositions. Devrim (2015) illustrated such metaphorical realizations and classified logical metaphors into four subtypes, namely, *cause as verb, cause as noun, cause as adjective*, and *cause as preposition*.

It has been frequently proposed in the literature on how the occurrence of logical metaphors contributes to academically valued meaning-making (e.g., Halliday, 1998; He & Yang, 2018; Liardét & Black, 2020). As Liardét (2013, p.168) noted, academic discourse values "the repositioning of reason within the clause rather than between clauses". However, existing studies of GM have mostly

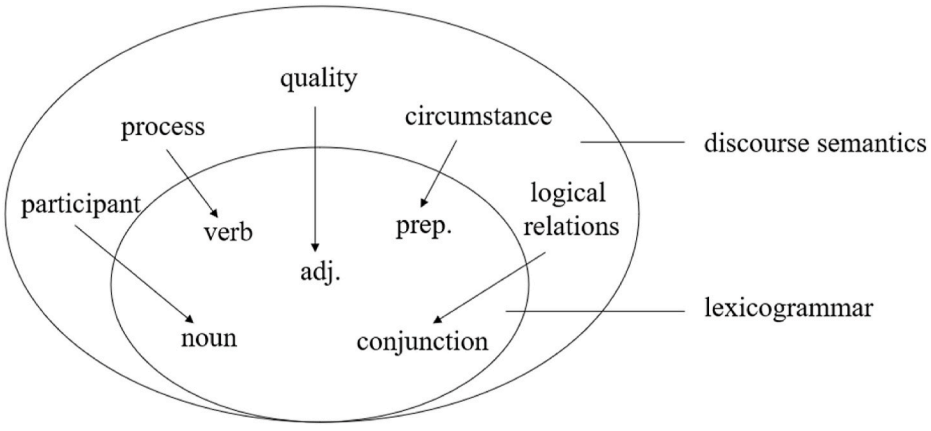

Fig. 1. Congruent realization of ideational meanings (adapted from Liardét, 2013).

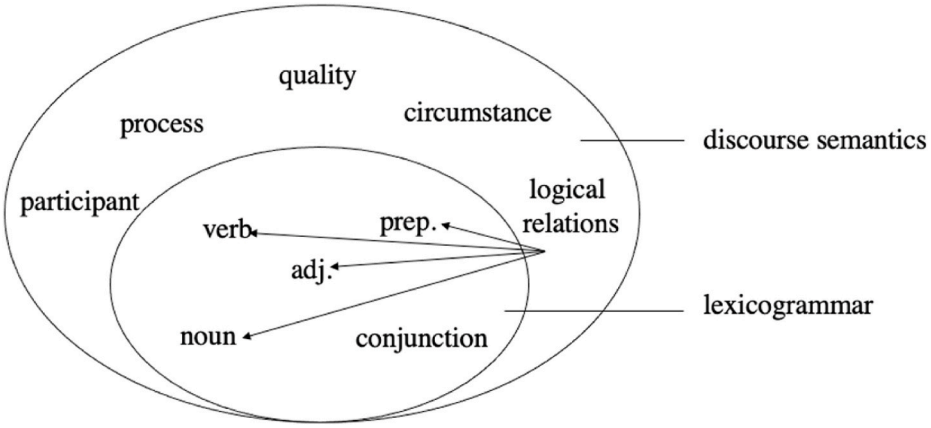

Fig. 2. Incongruent realization of logical relations (adapted from Devrim, 2015).

focused on interpersonal metaphors (Liardét, 2018) and experiential metaphors such as by investigating nominalization (He & Yang, 2018; Hu & Perez, 2022; Liardét, 2016), with few studies exploring the realization of logical metaphors in EFL learners' argumentative writing. A few relevant attempts have been made involving the comparison of the use of logical metaphors in student essays of different levels. For instance, Müller González (2019) found that undergraduate students use more types of GM, including logical metaphors, than high school students, and that the use of logical metaphors was not consistently appropriate. Comparing the texts from first-year and fourth-year Chinese EFL learners, Liardét (2013) similarly found that advanced learners were more inclined to achieve cohesion through cause-and-effect networks with more instances of GM, but their texts occasionally involved disorganized logical structure. It is evident that the features of students' use of logical metaphors in writing were insufficiently investigated, such as its distribution and wordings. In addition, whether and how writing instruction would affect EFL students' use of logical metaphors in argumentative writing has also been underexplored. This study, therefore, builds on the literature to examine how writing instruction over one semester affects EFL students' deployment of logical metaphors. Drawing on the longitudinal dataset, this study further explores the features of logical metaphors in the argumentative writing of various grades. The findings are expected to shed light on the features of EFL students' deployment of GM, as well as the effectiveness of writing instruction on EFL students' academic literacy development. This study was guided by the following two research questions:

1) Is there any variation in the longitudinal distribution and wording of logical metaphors in EFL students' argumentative writing?
2) What are the differences in the frequency and wording of logical metaphors across student writing of various grades?

Table 1
Teaching procedure for writing task 5.

Teaching Sessions	Teaching Procedure	Teaching Content
Week 1	Topic introduction	Pose a lead-in question: Should psychological counselling be covered by national medical insurance?
	Context building	Discuss the following questions: (1) What do you know about psychological counselling? (2) In what circumstances will people turn to psychological counselling? (3) Do you know how much it will cost for one counselling session? (4) How does psychological counselling become a controversial issue?
	Model essay deconstruction	Analyze the content, language, and organization of the model essay entitled *The Homeopathy Debate*. • Content: how the author constructs logical reasoning and expresses academic argument • Language: how the author uses grammar and vocabulary • Organization: how the author structures the text, including within each paragraph and between the paragraphs
	Preparation for collaborative writing	Decide an agreed statement and persona for joint construction, for example, a psychological consultant who gives "Psychological counselling should be covered by national medical insurance". Brainstorm supporting evidence and examples that could be potentially used in the joint construction and construct an agreed outline.
Week 2	Collaborative writing	Students are divided into five small groups. Students in each group should collaborate in writing one paragraph.
	Whole class joint revision	The five paragraphs are combined into a draft essay, and all the students jointly revise the draft under the guidance of the teacher.
Week 3	Teacher feedback	The teacher provides feedback on the common issues found in the students' independent writing, for example, grammar mistakes, logical fallacies, improper examples, etc.
	Peer feedback	Students work in pairs and give feedback to their peer's independent writing.
	Revision and submission	Students further revise their drafts based on the feedback from the teacher and their peers and submit the final version to the teacher.

Table 2
Coding scheme of logical metaphor.

Subtypes	Description	Examples	Congruent examples	Possible tokens
Cause as verb	Logical relation is construed through the use of verb	Reckless behaviors of people without professional skills may cause more problems.	There may be more problems because people without professional skills behave recklessly.	cause bring lead to result in
Cause as preposition	Logical relation is construed through the use of preposition	I think it should be forbidden to operate on teens due to the negative influence that could bring to teenagers.	I think it should be forbidden to operate on teens because it could bring negative influence to teenagers.	due to in order to owning to because of thanks to
Cause as noun	Logical relation is construed through the use of noun	The primary causes of this situation include the public's superficial knowledge of psychological problems and the financial burden of treatment.	This situation occurs, because the public have superficial knowledge of psychological problems and financial burden of treatment.	reason factor consequence cause result
Cause as adjective	Logical relation is construed through the use of adjective	Knowledge gained from books is also beneficial to the horizon-broadening of people.	People's horizon could be broadened because they have gained knowledge from books.	beneficial vital critical reasonable effective

3. Methods

3.1. Research context and participants

This study was carried out in one of the top-notch universities in China. With the aim of cultivating globalized talents, the university offers compulsory English courses for all undergraduate students for two years. In this study, participants were 22 Chinese freshmen from an intact class with 8 males and 14 females. The ages of the students were from 18 to 20 years old ($M = 18.14$, $SD = 0.468$). They were all majoring in International Politics. They had learned English as a foreign language for at least 10 years and had passed the national college entrance examination. None of the participants had received instruction on academic writing before participating in the study. At the time of data collection, they were enrolled in a compulsory English writing course taught by a Chinese female lecturer with three years of English writing teaching experience. Informed consent was obtained from all students and the teacher before data collection.

3.2. Instruction and text collection

The writing course lasted for 16 weeks and was scheduled once a week (one and half an hour class). Every three weeks (except the first week) comprised one teaching unit in which one writing task was assigned to students. Every unit followed the same teaching procedure, as exemplified in Table 1 by using Task 5 as an example. The first week mainly involves topic introduction, context building, and model essay deconstruction. In particular, in the step of model essay deconstruction, the teacher would draw students' attention to the content, language, and organization of the essay. After class, students were asked to search for relevant resources on the writing topic with which they would collaborate in groups to write paragraphs in Week 2. The teacher would then combine the paragraphs written by different groups into one draft essay and guide students to revise together, during which the aspects of content, language, and organization of essay writing were again emphasized. Students would then write an essay on the same topic independently as after class assignment and submit it to the teacher two days prior to the next class. In the third week, the teacher would first provide feedback on issues commonly found in students' independent writing, relating to the aspects of content, language, and organization. Students would then work in pairs to give feedback to each other's essays focusing on the same aspects. With all the feedback, students would revise their own draft and submit the final version to the teacher. To be noticed, no explicit instruction of logical metaphors was provided in the writing instruction since the teacher was restricted by the official syllabus and was given little flexibility to teach GM which is not included in the writing instruction textbooks.

Data were collected immediately after each teaching unit. The collected texts were first screened for plagiarism checking and no text was removed at this step. Altogether, 110 valid texts with 46,091 total words were collected for the study. All the written texts were labelled according to student numbers and writing tasks for subsequent analysis. For example, S11-WT3 stands for the text of writing task 3 written by student No. 11.

3.3. Text scoring and annotation

After data collection and plagiarism checking for each writing task, the teacher graded the texts into Grades A (high-scored, 80 and above), B (median-scored, 60 to 80) or C (low-scored, 60 and below) respectively, according to the standardized assessment rubrics for the course, evaluating three aspects of writing: (1) content, namely the ability to express logical reasoning and academic arguments, which composed 35% of the grade; (2) language, namely the ability to write grammatically accurately with accurate use of vocabulary, which also composed 35% of the grade; (3) organization, namely the ability to structure an academic text, which composed 30% of the grade. The identification information of students was temporarily removed during the grading process in order to avoid potential subjective bias of grading.

We then conducted manual coding to annotate tokens of logical metaphors in students' texts by using NVivo 12, considering that omissions and atypical examples can be effectively reduced with manual coding. To avoid potential bias, the texts of each writing task were analyzed independently. We drew on a coding scheme (see Table 2) adapted from Devrim's (2015) integrated model of logical metaphors, which categorized logical metaphors into four subtypes: *cause as verb, cause as preposition*, *cause as noun,* and *cause as adjective*. The overall rules for defining and identifying logical metaphor tokens are to seek for evidence of causal relationships and whether the sentence could be expressed in a congruent way without employing the tokens, such as by using conjunctions. Here, we use examples excerpted from students' writing to illustrate how tokens of each subtype were identified.

3.3.1. Cause as verb

Example 3.1. Reckless behaviors of people without professional skills may cause more problems. (S3-WT1)

In Example 3.1, "cause" links the nominal groups "reckless behaviors" and "more problems" in the Theme and Rheme positions. It could be seen as a logical metaphor because it serves as the Process to manage causality inside the clause, and the clause can be worded congruently as in "There may be more problems because people without professional skills behave recklessly."

3.3.2. Cause as preposition

Example 3.2. I think it should be forbidden to operate on teens due to the negative influence that could bring to teenagers. (S17-

WT2)

In Example 3.2, the logical relation is construed through the use of "due to". It links the clause "I think it should be forbidden to operate on teens" and the nominal group "the negative influence that could bring to teenagers". The congruent expression of this sentence could be "I think it should be forbidden to operate on teens because it could bring negative influence to teenagers", which uses Relator to link two clauses. Thus, in this case, "due to" is considered a logical metaphor.

3.3.3. Cause as noun

Example 3.3. The primary causes of this situation include the public's superficial knowledge of psychological problems and the financial burden of treatment. (S14-WT5)

Example 3.3 showcases how "cause" is used as a noun to convey causality inside the clause. It manages the logical relationship between "public's superficial knowledge" and "this situation". The sentence can be worded congruently as in "This situation occurs because the public have superficial knowledge of psychological problems and financial burden of treatment."

3.3.4. Cause as adjective

Example 3.4. Knowledge gained from books is also beneficial to the horizon-broadening of people. (S5-WT4)

Example 3.4 showcases how "beneficial" is used as an adjective to create a causal relation within a clause. It is in the Rheme position and links the two nominal groups "knowledge gained from books" and "the horizon-broadening of people". The sentence can be worded congruently as in "People's horizon could be broadened because they have gained knowledge from books." During the coding procedure, we were particularly careful to determine if an adjective indicated a causal relationship. For instance, one student wrote that "Psychological well-being … is closely related to harmonious development of society (S2-WT5)", in which the adjective "related" denotes a correlation rather than a cause-effect relationship. In this case, therefore, the adjective is not identified as a logical metaphor token. On the other hand, "related" could be recognized as a logical metaphor token if the sentence were worded as "The harmonious development of society is related to the increased psychological well-being of citizens."

We first annotated five texts together to familiarize the coding scheme and then annotated the rest of the texts independently. The inter-coder agreement was 84%, indicating satisfactory reliability (Cohen, 1992). Disagreements were resolved through discussion. The raw frequencies of each subtype of logical metaphor were calculated. Table 3 describes the number of annotated items in the five writing tasks. Raw frequencies of logical metaphors in each written text were then converted into normalized frequencies per 1000 words for subsequent statistical analysis and wordlist generation.

3.4. Data analysis

Statistical tests were conducted via SPSS 25. Non-parametric tests were performed as the frequencies were in non-normal distribution according to the Shapiro-Wilk tests. In particular, Friedman's ANOVA was used to explore the longitudinal changes in the frequencies of logical metaphors in students' argumentative writing. Wilcoxon signed-ranks tests were used as the post-hoc test for pairwise comparisons. Bonferroni corrections for p values were used where there were multiple comparisons to avoid Type I errors and false significance (Field, 2018). Kruskal-Wallis tests were performed to explore the differences in the frequencies of logical metaphors among high-, median-, and low-scored texts. Mann Whitney U tests with Bonferonni corrections were used as the post-hoc test for pairwise comparisons. We further conducted word frequency analysis with NVivo 12 to generate word list and sentence examples for each subtype of logical metaphors.

4. Results

4.1. Longitudinal variation in L2 expression of logical metaphors

Table 4 presents variations in the longitudinal distribution of logical metaphors in students' texts across five writing tasks. Results of Friedman's ANOVA revealed a statistically significant rise in the total frequencies of logical metaphors (χ^2 (4) = 22.51, $p < 0.001$). Post-hoc pairwise comparisons revealed a significant increase of total logical metaphors in Task 2, 3 and 5 over Task 1 (1 vs. 2, $p = 0.042$; 1 vs. 3, $p = 0.008$; 1 vs. 5, $p < 0.001$). The increase in logical metaphors in general is presumably suggestive of an influence of

Table 3
Annotated items per writing task.

Writing Tasks	Cause as verb	Cause as prep.	Cause as noun	Cause as adj.	Total
Task 1	21	31	13	2	67
Task 2	70	31	17	3	121
Task 3	100	25	11	9	145
Task 4	50	47	18	14	129
Task 5	119	43	10	12	184
Total	360	177	69	40	646

Table 4
Longitudinal changes in the frequencies of logical metaphors.

Types	Task Time	Mean [a]	*SD*	Friedman's ANOVA	Pairwise comparison [b]
Cause as verb	1	2.76	4.12	χ^2 (4) = 42.62, $p < 0.001$	1 vs. 2, $z = -2.10$, $p = 0.001$
	2	8.25	4.38		1 vs. 3, $z = -5.34$, $p < 0.001$
	3	10.68	4.75		1 vs. 5, $z = -5.44$, $p < 0.001$
	4	5.47	3.04		4 vs. 3, $z = 3.24$, $p = 0.012$
	5	12.25	7.38		4 vs. 5, $z = -3.34$, $p = 0.008$
Cause as preposition	1	4.18	3.89	χ^2 (4) = 8.14, $p = 0.087$	*N/A*
	2	3.64	2.31		
	3	2.43	2.50		
	4	5.14	3.88		
	5	4.21	3.28		
Cause as noun	1	1.55	2.05	χ^2 (4) = 2.73, $p = 0.604$	*N/A*
	2	2.01	2.76		
	3	1.18	1.82		
	4	1.92	2.76		
	5	0.97	1.81		
Cause as adjective	1	0.22	0.72	χ^2 (4) = 8.27, $p = 0.082$	*N/A*
	2	0.38	0.99		
	3	1.06	1.78		
	4	1.71	2.54		
	5	1.19	1.48		
Total	1	8.72	6.16	χ^2 (4) = 22.51, $p < .001$	1 vs. 2, $z = -2.86$, $p = 0.042$
	2	14.28	6.12		1 vs. 3, $z = -3.34$, $p = 0.008$
	3	15.34	5.36		1 vs. 5, $z = -4.58$, $p < 0.001$
	4	14.23	5.03		
	5	18.63	8.64		

[a] Frequency of each type is standardized as frequencies per 1000 words.
[b] Only statistically significant pairs are presented.

the writing instruction which emphasized the need for logical reasoning in argumentative writing. For the four subtypes of logical metaphors, results showed that the frequencies of *cause as verb* changed significantly over the five writing tasks (χ^2 (4) = 42.62, $p < 0.001$). Post-hoc tests revealed a significant increase of *cause as verb* in Task 2, 3 and 5 over Task 1 (1 vs. 2, $p = 0.001$; 1 vs. 3, $p < 0.001$; 1 vs. 5, $p < 0.001$), and in Task 3 and 5 over Task 4 (4 vs. 3, $p = 0.012$; 4 vs. 5, $p = 0.008$). However, no significant changes were found in the frequencies of the other three subtypes, namely, *cause as preposition*, *cause as noun*, and *cause as adjective*. The finding in the subtypes of logical metaphors indicates that the participating students granted more attention to the use of verbs, rather than of prepositions, nouns, and adjectives, to demonstrate logical reasoning within clauses in argumentative writing.

In terms of the differences in wordings, Table 5 presents the distribution of the five most frequent wordings across the five writing tasks. For *cause as verb*, the most frequently used token in the first two writing tasks was "cause", which indicates a general causal relationship. It can be noted that in Task 3, the most frequently used word was "promote", emphasizing a positive effect in a causal relationship. Such verbs with specific connotations (e.g., strengthen, mitigate, underpin, stimulate, alleviate, see the full wordlist in Appendix A) occurred more frequently and with greater variety in Task 3 and the following two tasks, indicating that students gradually deployed verbs to express logical meanings in a more varied and accurate way. In analyzing the lexical expressions of logical metaphors, semantic prosody was also considered, that is, whether certain words exhibit a tendency to co-occur with particular semantic sets that give rise to negative, positive or neutral connotative meanings (Stubbs, 2001; Zhang, 2021). In our dataset, "cause" was commonly found with nouns indicating negative consequences such as "damage", "problem" or "harm", suggesting that students used it in ways that aligned closely with appropriate semantic prosody (Li & Jiao, 2013; Stubbs, 2001).

1) The most direct result caused by it is people are more and more unwilling to give a hand to anyone in difficulty even it's just a piece of cake. (ST11-WT1)
2) Furthermore, such mandatory military service strengthens the capacity of protection, preparing people for the unknown future. (ST5-WT3)
3) Above all, psychological counselling being covered by national medical insurance can alleviate the trend of mental problems towards more widespread and serious. (ST10-WT5)

For *cause as preposition*, "because of" and "in order to" were used most frequently in Task 1. However, they occurred less frequently in the following writing tasks. In contrast, "due to", whose frequency ranked fifth in Task 1, became the most frequently used word in Task 2, 3 and 5. It was commonly found to co-occur with nominal expressions that have either positive, negative, or neutral attitudinal meaning, such as "immatureness", "victory", or "experience".

Table 5
Wordings of logical metaphors across writing tasks.

WT1	Raw/Norm Freq.		WT2	Raw/Norm Freq.		WT3	Raw/Norm Freq.		WT4	Raw/Norm Freq.		WT5	Raw/Norm Freq.	
Cause as verb														
cause	7	0.91	cause	15	1.72	promote	16	1.69	make	11	1.18	cause	19	1.83
result	5	0.65	bring	11	1.26	bring	10	1.06	play a role	6	0.65	promote	10	0.96
bring	2	0.26	lead to	8	0.92	cause	7	0.74	enable	5	0.54	lead to	12	1.16
lead to	2	0.26	affect	7	0.80	enhance	6	0.63	enhance	5	0.54	make	9	0.87
decrease	1	0.13	influence	4	0.46	create	5	0.53	help	3	0.32	reduce	6	0.58
Cause as prep.														
because of	7	0.91	due to	11	1.26	due to	9	0.95	by	13	1.40	due to	17	1.64
in order to	7	0.91	in order to	6	0.69	in order to	4	0.42	through	12	1.29	in order to	6	0.58
out of	6	0.78	because of	4	0.46	by	3	0.32	without	12	1.29	with	6	0.58
by	3	0.39	concerning	3	0.34	considering	3	0.32	in order to	4	0.43	because of	5	0.48
due to	3	0.39	by	2	0.23	because of	2	0.21	with	3	0.32	through	3	0.29
Cause as noun														
reason	9	1.16	reason	9	1.03	reason	3	0.32	foundation	4	0.43	factor	2	0.19
consequence	1	0.13	factor	5	0.57	effect	2	0.21	result	3	0.32	impact	2	0.19
factor	1	0.13	consequence	1	0.11	factor	2	0.21	basis	2	0.22	influence	2	0.19
ground	1	0.13	consideration	1	0.11	influence	2	0.21	factor	2	0.22	cause	1	0.10
result	1	0.13	effect	1	0.11	concern	1	0.11	role	2	0.22	effect	1	0.10
Cause as adj.														
reasonable	1	0.13	beneficial	2	0.23	beneficial	2	0.21	essential	4	0.43	beneficial	6	0.58
understandable	1	0.13	reasonable	1	0.11	conductive	2	0.21	beneficial	1	0.11	conductive	2	0.19
						essential	2	0.21	critical	1	0.11	necessary	2	0.19
						necessary	1	0.11	crucial	1	0.11	effective	1	0.10
						reasonable	1	0.11	efficient	1	0.11	harmful	1	0.10

4) Due to the immatureness of teenagers' body, those mechanical devices may at a high risk leave scars on teenagers' skin, even many hidden dangers. (ST12-WT2)
5) Due to his victory, the 26-year-old Korean avoided carrying out the two-year mandatory military service expected of his countrymen, which brought a controversial issue. (ST7-WT3)
6) Meanwhile, some people who deny this dangerous rescue might be more satisfied to keep themselves in comfort zone due to their experiences or backgrounds. (ST15-WT1)

In terms of *cause as noun*, "reason" was the token with the highest frequency in the first three writing tasks. However, it was not found in the top five wordings in the last two writing tasks. The noun that was frequently found in all the five writing tasks was "factor". In our dataset, it was often used to refer to the previously mentioned reason in a cause-effect relationship.

7) These factors are assuredly dropping the level of military inch by inch, which is directly related to the defence power. (ST9-WT3)
8) The same is true of a UK survey, in 2019, academic institutions that look at the student experience as a key factor in the battle to attack the best applicants are on the rise. (ST2-WT4)

For *cause as adjective*, few tokens were found in the first two writing tasks, while from Task 3, students' use of adjectives to manage causality within the clause increased and became more varied. One word that was found in most writing tasks was "beneficial", which indicated a positive consequence in a cause-effect relationship.

9) In addition, plastic surgery helps teenagers to be themselves and is beneficial for their physical and mental health. (ST22-WT2)

In summary, the subtype of *cause as verb* shows a trend of changing from general to specific connotation in causality conveying. The two subtypes, *cause as prep* and *cause as noun*, show a similar repertoire across five writing tasks. Whereas for the subtype of *cause as adjective*, students adopted more varied tokens in the last three writing tasks.

4.2. Logical metaphors and writing scores

In all the collected written texts, 30 texts were scored as "A", 37 texts as "B", and 43 texts as "C", according to the writer's ability of logical reasoning and academic argument construction. Table 6 shows the use of logical metaphors in all the texts graded A to C. Results of Kruskal-Wallis tests showed that there was a significant effect of writing scores on the total frequencies of logical metaphors (H (2) = 19.74, $p < 0.001$). Post-hoc tests revealed significant differences in the total frequencies of logical metaphors between the high-scored and low-scored texts (A vs. C, $p < 0.001$), and between median- and low-scored texts (B vs. C, $p = 0.002$). With regard to the four subtypes of logical metaphors, a significant effect of writing scores was found on the frequencies of *cause as verb* (H (2) = 15.46, $p < 0.001$). Post-hoc tests revealed that there were significant differences in the frequencies of *cause as verb* between the high-scored and low-scored texts (A vs. C, $p < 0.001$), and between median- and low-scored texts (B vs. C, $p = 0.025$). Whereas no significant effect of writing scores was detected on the frequencies of the other three subtypes (i.e., *cause as preposition*, *cause as noun*, and *cause as adjective*). The finding suggests that compared with low-scored texts, high- and median-scored texts involved more logical metaphors in constructing logical reasoning and argumentation, particularly by using a greater number of verbs.

Table 7 presents the five most frequent wordings of each subtype of logical metaphors across and particular to a given grade. For

Table 6
The frequencies of logical metaphors across writing scores.

Types	Writing scores (*N*)	Mean [a]	*SD*	Kruskal-Wallis	Pairwise comparison [b]
Cause as verb	A (30)	10.48	6.32	H (2) = 15.46, $p < 0.001$	A vs. B, $z = 1.25$, $p = 0.629$
	B (37)	9.05	6.52		**A vs. C, $z = 3.78$, $p < 0.001$**
	C (43)	5.06	3.74		**B vs. C, $z = 2.63$, $p = 0.025$**
Cause as preposition	A (30)	4.84	2.95	H (2) = 5.49, $p = 0.064$	*N/A*
	B (37)	3.89	3.74		
	C (43)	3.30	3.06		
Cause as noun	A (30)	1.52	2.34	H (2) = 1.20, $p = 0.551$	*N/A*
	B (37)	1.91	2.62		
	C (43)	1.20	1.87		
Cause as adjective	A (30)	1.02	1.87	H (2) = 0.11, $p = 0.946$	*N/A*
	B (37)	0.91	1.69		
	C (43)	0.84	1.59		
Total	A (30)	17.86	7.88	H (2) = 19.74, $p < 0.001$	A vs. B, $z = 0.83$, $p = 1.000$
	B (37)	15.77	6.65		**A vs. C, $z = 4.06$, $p < 0.001$**
	C (43)	10.40	4.63		**B vs. C, $z = 3.40$, $p = 0.002$**

[a] Frequency of each type is standardized as frequencies per 1000 words.
[b] Bold = statistically significant.

Table 7
Wordings of logical metaphors across grades.

Grade A	Raw/Norm Freq.		Grade B	Raw/Norm Freq.		Grade C	Raw/Norm Freq.	
Cause as verb								
cause	13	0.89	cause	24	1.60	cause	11	0.69
bring	13	0.89	make	12	0.80	bring	8	0.50
lead to	12	0.82	lead to	11	0.73	promote	7	0.44
enhance	10	0.69	promote	9	0.60	affect	4	0.25
promote	10	0.69	bring	6	0.40	lead to	4	0.25
Cause as prep.								
due to	20	1.37	due to	12	0.80	because of	10	0.62
by	11	0.75	in order to	11	0.73	due to	9	0.56
in order to	11	0.75	through	8	0.53	by	8	0.50
because of	6	0.41	without	8	0.53	in order to	5	0.31
through	5	0.34	by	4	0.27	without	5	0.31
Cause as noun								
factor	5	0.34	reason	7	0.47	reason	11	0.69
reason	4	0.27	factor	4	0.27	factor	3	0.19
consequence	2	0.14	influence	4	0.27	result	2	0.12
impact	2	0.14	foundation	3	0.20	base	1	0.06
cause	1	0.07	effect	2	0.13	basis	1	0.06
Cause as adj.								
beneficial	4	0.27	essential	3	0.20	beneficial	3	0.19
conducive	2	0.14	beneficial	3	0.20	necessary	3	0.19
reasonable	2	0.14	indispensable	1	0.07	essential	2	0.12
critical	1	0.07	important	1	0.07	conducive	1	0.06
effective	1	0.07	harmful	1	0.07	profitable	1	0.06

cause as verb, "cause" was the most frequently used word across all grades. Sentence examples show that it is often collocated with negative meanings such as "adverse effects", "anger", or "problem", indicating a negative semantic prosody.

10) Since teenagers' bodies are not fully mature, they are likely to cause adverse effects, including local and systemic infections and allergic reactions. (ST4-WT2-GradeA)
11) It is likely that obligatory national service would cause civilian argument and anger which makes a bad influence on national unity. (ST10-WT3-GradeB)
12) The behavior of you doesn't always save lives, it could actually cause more problems. (ST14-WT1-GradeC)

Qualitative differences could be further noted in the way the word "cause" was used. It was found that high- and median-scored texts had a more varied usage of "cause". For example, "caused by" was frequently found in both high- and median-scored texts, which was seldomly found in low-scored texts.

13) Because of the great stress caused by the absurdities of life, they may vent emotion through drug abuse, robbery and vandalism. (ST6-WT5-GradeA)
14) The death rate caused by depression is about 4.0%–10.6%. (ST9-WT5-GradeB)

Our dataset also showed that another verbal phrase, "lead to", was frequently used in the texts across all grades and served as a positive predictor of the grade. Students who frequently used the verbal phrase for in-clause causality tend to be likely to receive high or median grades. Additionally, this verbal phrase was found in high- and median-scored texts to be followed by nominal expressions indicating negative consequences (e.g., concern, casualty), which is considered an appropriate semantic prosody (Li & Jiao, 2013), while it was often used together with positive consequences in low-scored texts. Also, the phrase in present participle form (e.g., excerpt 15) was found in both high- and median-scored texts, but it was not detected in low-scored texts.

15) According to the report from USA today, Lorna Breen, the medical director of the emergency department at New York-Presbyterian Allen Hospital, committed suicide due to the tremendous mental pressure, leading to a widespread concern about mental health. (ST14-WT5-GradeA)
16) These could lead to high casualty rate among soldiers drafted under compulsory military service. (ST3-WT3-GradeB)
17) It leads to a much *deeper understanding* of a concept through the act of doing and personal experience. (ST22-WT4-GradeC)

Qualitative differences were also detected in the use of "result" in the texts of different grades. Expressions such as "result from" and the present participle form of "resulting in" were only found in high- and median-scored texts but were not found in low-scored texts.

18) Words came that there were two doctor suicides in the United States on April 25 and 26, which resulted from huge psychological pressure. (ST10-WT5-GradeB)
19) That is to say, professional counselling is often unaffordable to most people, resulting in the few demands of mental health services. (ST5-WT5-GradeA)

In terms of *cause as preposition*, "due to" with high frequency across all grades, was a positive predictor of the grade. Students who frequently build cause-effect networks by using "due to" would be more likely to receive higher grades. As a word with mixed semantic prosody (Li & Jiao, 2013), "due to" could co-occur with positive, negative, or neutral consequences. While instances of negative and neutral semantic prosody were detected in the texts across all grades, positive semantic prosody was only found in high- and median-scored texts.

20) Due to his victory, the 26-year-old Korean avoided carrying out the two-year mandatory military service expected of his countrymen, which brought a controversial issue. (ST7-WT3-GradeA)
21) But the research indicates that a lot of this self-consciousness goes away with time due to the self-satisfaction is connected with various factors. (ST5-WT2-GradeB)

For *cause as noun*, "reason" and "factor" were found with high frequency across all grades. The token "reason" was a negative predictor of the grade, while "factor" was a positive predictor. In terms of *cause as adjective*, "beneficial" was detected in the texts of different grades.

22) One reason many teens seek plastic surgery is that teens often want to fit in with others and meet the expectations of anyone else. (ST3-WT2-GradeC)
23) These factors are assuredly dropping the level of military inch by inch, which is directly related to the defense power. (ST9-WT3-GradeC)
24) Generally speaking, psychological counselling could be beneficial to cut down the suicide rate. (ST11-WT5-GradeB)

In summary, high- and median-scored texts not only involved more logical metaphors overall, but also demonstrated more appropriate use of certain expressions. Low-scored texts, in contrast, involved fewer instances of logical metaphors that were sometimes inaccurately used.

5. Discussion

This study has explored the longitudinal development of EFL students' use of logical metaphors in argumentative writing as a result of academic writing instruction, including the frequency and wording of linguistic markers across one semester, as well as the differences in the use of logical metaphors across student texts of various grades.

Through both quantitative and qualitative analysis of the data, this study found a significant longitudinal change in students' use of logical metaphors overall, as revealed by the total frequencies in five writing tasks, indicating the effectiveness of the writing course in improving students' use of logical metaphors. This result is encouraging in that the teacher did not introduce logical metaphors explicitly throughout the writing instruction, which suggests that implicit instruction could also prompt students to build causality within clauses by using logical metaphors. Our finding provides further evidence to Liardét's (2013) contention that learners could develop their ability to use GM with implicit instruction. One possible reason for students' development in using logical metaphors could be attributed to their increased knowledge of the target genre which features logical reasoning and academic argumentation. Model essays might have played a vital role in this regard since the focus of model essay deconstruction was on language, grammar and organization within and between clauses, and a discussion on the expression of causality was present, even if it was not formulated in SFL terms (logical metaphors etc.). In addition, with the teacher's consistent emphases on logical reasoning in the writing processes, students became more aware of the ideational meanings in certain communicative situations and are more capable of choosing appropriate linguistic resources for logical reasoning, including logical metaphors, to achieve valued meaning in academic writing (Huang & Zhang, 2020; Yasuda, 2015).

Among the four subtypes of logical metaphors, the significant increase in students' use of *cause as verb* serves as the main contribution to the change of logical metaphors overall. This indicates that students preferred to build in-clause causality by using verbs, instead of prepositional phrases, nouns, and adjectives. The congruent Relators were thus most often reconstructed as metaphorical Processes (e.g., "cause", "lead to") (see also Liardét, t2013, 2016). Our finding aligns with Devrim's (2015) finding that L2 students most frequently employed verbs to construct cause-and-effect relationships inside the clause. The following reasons could possibly explain students' propensity for *cause as verb* in the current study. For one thing, verbalization is a typical incongruent realization of cause and effect networks (Martin & Rose, 2003; He & Yang, 2018). For another, the participating students affected by their L1 Chinese background were used to construct sentences by using verb phrase-based bundles (Shin, 2019; Zhang et al., 2021). As indicated in previous studies (Dong, 2021; Dong & Fang, 2021), when describing actions, Chinese as a dynamic language features the congruent use of verb phrases, whereas English, being a static language, prefers to use adjectives, adverbs, nouns, or prepositions. The impact of writing instruction in this study, which involves implicit instruction of GM, is thus to prompt them to build in-clause causality by using their most familiar devices. Another interesting finding worth mentioning is that the instances of *cause as verb* dropped dramatically in the fourth writing task after it stably increased in the first three writing tasks. This suggests that students'

utilization of logical metaphors exhibits a nonlinear developmental trajectory; at times, their development may regress to a less proficient state. This finding is consistent with Liardét's (2013) study in which the GM detected in the participants' texts was not always employed appropriately to achieve the function of technicality, lexical density, and cohesive organization. Müller González (2019) also pointed out that students' use of GM sometimes was inappropriate. This further echoes the recent contention that learning L2 writing is a complex and dynamic process (Han & Hiver, 2018; Larsen-Freeman & Cameron, 2008; Man & Chau, 2019).

In terms of logical metaphors and writing scores, significant differences in the total frequencies of logical metaphors were detected when comparing high- (A, 80 and above) and median-scored texts (B, 60 to 80) with low-scored texts (60 and below). It is revealed that the former deployed a larger quantity of logical metaphors with better appropriateness than the later did. Our finding gives further evidence to the previous contention that students' deployment of GM is a major indicator of the perceived success of the written texts (Devrim, 2015; Liardét, 2016; Schleppegrell, 2004). As shown in the results, a greater variety of expressions, such as "caused by", "resulted from", and the present particle form of "lead in" were detected in both high- and median-scored texts, and high- and median-proficient students used logical metaphors in a more appropriate manner in terms of semantic prosody. For instance, according to Li and Jiao's (2013) finding based on the Corpus of Contemporary American English (COCA; Davies, 2012), "lead to" is a verbal phrase that usually has a negative semantic prosody. In the present study, however, it often co-occurred with positive semantic prosody in low-scored texts, suggesting that the inappropriate use of linguistic resources may hinder the perceived success in presenting a logical argument. Similarly, "due to" is a prepositional phrase that has mixed semantic prosody, i.e., positive, negative, or neutral semantic prosody (Li & Jiao, 2013). In low-scored texts, the phrase was usually used together with negative or neutral semantic prosody. In short, our study found that the use of logical metaphors varied in terms of quality across the texts of different grades. The finding is partly in agreement with Liardét's (2016) study in that compared with low-scored texts (64 and below), high-scored texts (75 and above) demonstrate higher control and proficiency over the construal of metaphorical cause-and-effect networks. However, our finding is inconsistent with Liardét's (2016) revelation of no salient difference in the frequency of logical metaphors between high- and low-scored texts. This discrepancy may be attributed to the disparity in data size between the two studies. Liardét (2016) analyzed ten texts comprising approximately 11,100 words, whereas the current study involved 110 texts totaling 46,091 words. Additionally, the divergence in the language background of the participants may have contributed to the differing findings. Liardét's (2016) study primarily involved L1 English speakers, while the participants in our study were exclusively L2 writers.

6. Conclusion

This study explored the longitudinal development of Chinese EFL students' deployment of logical metaphors in argumentative writing across one semester's writing instruction. Our finding revealed a statistically significant rise in the total frequency of logical metaphors, particularly the subtype of *cause as verb*, and a trend of increasingly varied and accurate wordings of logical metaphors when students build in-clause causality. Stark differences were detected in the quantity as well as the quality of logical metaphors that students deployed, when comparing texts of various grades. To be specific, compared with low-scored texts, high- and median-scored texts exhibit more frequent and appropriate use of logical metaphors, particularly in terms of using verbs, when constructing logical reasoning and argumentation. Our study has provided additional evidence for the effectiveness of implicit instruction in facilitating students' capacity of deploying grammatical metaphors in writing. We have further shown that the analysis of students' use of logical metaphors can be helpful for the identification of key features contributing to successful argumentative writing. Our analysis in this study has also provided methodological insights for the exploration of logical reasoning in L2 writing through the lens of SFL.

This classroom-based study offers several pedagogical insights relating to EFL learners' use of logical metaphors for academic argumentation. Firstly, although EFL students improved in their use of logical metaphors as a result of implicit instruction in this study, it does not mean that teachers could completely overlook logical metaphors in writing instruction. As evidenced in our findings, it is vital for teachers to make clear the relationship between the use of logical metaphors and the perceived success of L2 academic writing. For instance, in teaching practice, teachers could introduce the features of argumentation and emphasize the role of logical reasoning in constructing a high-quality essay. Also, the teacher could make full use of model essay to showcase how logical reasoning between and within clauses was constructed in academic writing. Based on the findings of longitudinal variations in logical metaphors, we further recommend teachers to explicitly teach students to use prepositions, nouns, and adjectives to construe in-clause causality and guide students to use verbs appropriately while conveying logical reasoning. Explicit instruction in these aspects could be fruitful in raising students' awareness of achieving specific functions through the use of various linguistic markers. We also call for teachers' special attention on low-proficient students, who may be less competent in deploying logical metaphors to build causal relationships inside clauses.

We acknowledge that this study is subject to several limitations. Firstly, we did not involve a comparison group receiving explicit instruction on logical metaphors. For future research, comparing the effects of explicit and implicit instruction could help us better understand how students use logical metaphors. This, in turn, may offer fine-grained suggestions for improving students' proficiency in deploying GM in pedagogical practice. In addition, the writing instruction in this study lasted only for one semester. Further research with a longer duration of instruction is recommended to obtain a better understanding of EFL students' developmental trajectory in deploying logical metaphors for academic argumentation. Future studies could also explore students' perception of using logical metaphors as well as their perceived challenge in constructing cause-effect networks in argumentative writing, which can further inform course design to improve the effectiveness of writing instruction in an EFL context.

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Data availability statement

Data available on request from the authors. The data that support the findings of this study are available from the corresponding author, LZ, upon reasonable request.

CRediT authorship contribution statement

Di Wang: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft. **Lu Zhang:** Data curation, Funding acquisition, Project administration, Software, Supervision, Writing – review & editing. **Yu Huang:** Supervision, Writing – review & editing.

Declaration of competing interest

All authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.system.2024.103292.

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