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Writing in discipline-appropriate ways: An approach to teaching multilingual graduate students in mechanical engineering

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Introduction

Written communication is frequently addressed in talks on how to best prepare students for engineering practice. In surveys of employers and graduates [1]-[3], we witness a growing need for enhancing writing abilities of future engineers. Naturally, research on engineering writing has explored ways to provide course-level writing support for engineering students, especially for undergraduates [4]. Given that in U.S., students graduating with a bachelor's degree in engineering are mostly domestic-born native speakers of English [5], the current scholarship in Engineering Education has not yet addressed the specialized needs of foreign-born graduate-level multilingual students[1] for whom English is an additional language. For graduate students in engineering, one of the biggest challenges is to write about their scientific research in English-medium publications (e.g., conferences, journals, reports). However, students' abilities to write scholarly and effectively in an Anglo-American context vary greatly when they enter the graduate programs [6]. This case is further complicated by a substantial enrollment of multilingual graduate students, who possess even more variable writing experience in different cultural contexts [4].

Besides coping with a heterogeneous writing experience in engineering, graduate programs should also attend to the ever-increasing pressure to publish in English during graduate studies [7]. Arguably, a publication record now becomes the benchmark to assess a scholar's academic productivity, and as a result, plays a vital role in job applications and funding opportunities [8]. Important as it is, graduate students are often left unprepared to communicate the scientific work they have done and its significance through disciplinary academic writing (e.g., journal article), the genre of which is "foreign" even to U.S. domestic students [9]. Consequently, they learn the new writing expectations mostly on-the-job during apprenticeship, a process that is particularly upsetting for multilingual students [10], [11].

As such, it is imperative to explore how engineering programs have approached the instructional support of writing at the graduate level and to evaluate the outcomes for multilingual students. In this paper, I will first review the present scholarship of how engineering has incorporated communication pedagogy strategies into the teaching of academic and professional writing with emphases placed on the common types of writing support that graduate students in engineering receive and their limitations vis-à-vis multilingual student writers. Secondly, by explicating the potential of corpus-based writing instruction to teach effective sentence communication, a novel tutoring design will be described in detail to account for the limitations identified in the review. This work should contribute to the relatively little writing pedagogy research on graduate-level multilingual

[1] While the term "multilingual students" could also mean native speakers of English who learned an additional language such as French and Spanish, it is used here to mean international students whose native language is not English for the purpose of this study.

students in engineering, and can arouse institutional awareness to support their writing experience.

Graduate-Level Writing Support Available for Multilingual Student Writers in Engineering

Engineering educators have resorted to various writing resources and strategies available at course-, program-, department- and institution-level depending on the scale of the intervention. Successful attempts have been made mainly at (1) working with writing center tutors, (2) creating (in-house) discipline-specific writing-intensive course, (3) building up support groups consisting of peers, advisors and writing specialists. For the purpose of this study, I review below only first two areas of interest. For a fuller review of the current landscape of graduate-level writing support available in engineering, readers should refer to Batson [4].

Working with writing center tutors

As a university-wide service to students, employees and faculties who need professional support for any kind of writing task, writing centers have long served as a default solution to problems in writing. Engineering professors also commonly recommend the tutoring service at the writing center to those who struggle to communicate effectively. However, there are fewer centers catering specifically to the needs of engineering students [12] and resources are often allocated to undergraduate writing instruction [7]. More importantly, the tutoring can be very different between multilingual writers and English-native writers [13]. Silva [14] found that multilingual writers' writing processes (planning, reviewing) and products (fluency, quality) were distinctive from their English-native peers. Moreover, for graduate students who need discipline-specific support, having a tutor with limited academic writing experience in that field will likely face resistance for giving discipline-inappropriate advice [15]. As a result of doubt in tutors' domain-specific knowledge, engineering doctoral students were found to be the most difficult to attract in terms of willingness to work with writing centers [16].

Discipline-Specific Writing-Intensive Course

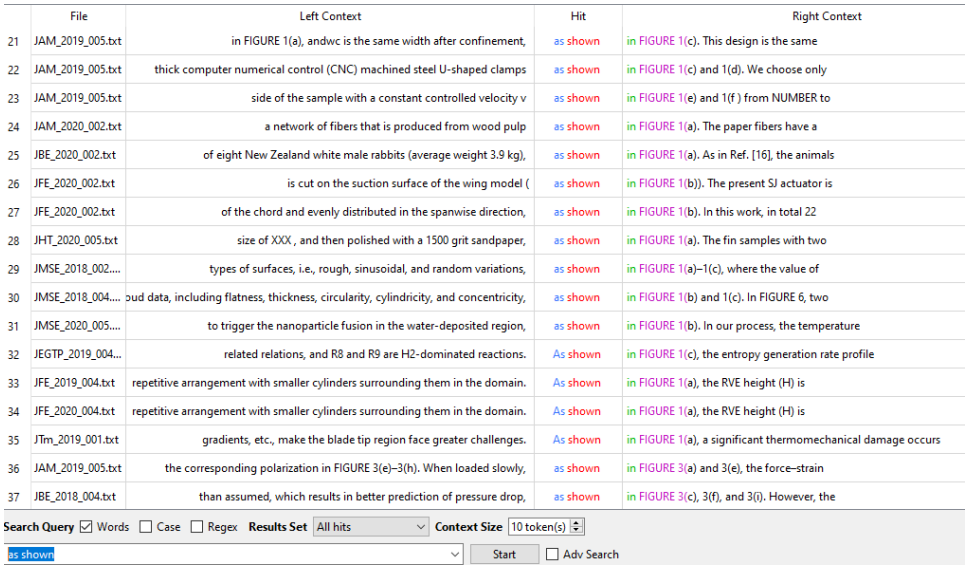
Situated within a complex sociocultural context, each discipline under engineering enjoys a specialized epistemology and rhetorical convention that are co-constructed and practiced by its members [17]. As newcomers to the discipline, graduate students are waiting to be apprenticed into their respective domain, sometimes through a discipline-specific writing course. According to research in disciplinary writing education, analyzing discipline-specific texts is an excellent starting point for writing instruction, allowing students to reflect on disciplinary norms and incorporate these practices into their own writing [17]. For example, Lax [18] developed an in-house writing course for graduate-level multilingual writers in Electrical and Computer Engineering. She leveraged Swalesian genre theory [19], sentence-level mechanics and exemplar articles to promote discipline-appropriate writing for

multilingual writers. Through a similar genre lens, Berdanier [20] investigated the extent to which the teaching and learning of Mechanical Engineering writing can support graduate students' familiarity with disciplinary discourse. Troy and Liang [21] collaboratively created a scientific writing course for Chinese doctoral students in Biomedical Engineering, covering rhetorical organization and format, grammar mechanics and audience awareness.

Viewing writing as a social process, genre-based pedagogy has made some progress in engineering writing over the past decades. However, it applies mainly in the teaching of rhetorical expectations of generic structure. The challenge of teaching lexicogrammar that realizes those rhetorical functions remains underexplored. Teaching appropriate lexicogrammar usage, especially sentence-level features, in engineering is crucial for engaging multilingual writers [22] given their growing representation in graduate studies in U.S. Thus, it seems timely for the current study to develop their writing skills and strategies for coping with challenges of effective communication at sentence-level.

The Potential of Corpus-Based Writing Instruction

In light of writing center tutors' lack of discipline-specific writing experience and genre-based pedagogy's lack of lexicogrammar training to guide writing-intensive course in engineering, I introduced here a pedagogical framework most vibrant in computer-assisted language learning research: corpus-based writing instruction. A corpus is a principled collection of computerized texts that can later be queried through a concordancer (e.g., AntConc, Wordsmith). Essentially, the corpus-based writing instruction prioritizes form-focused teaching by having learners notice the structural and grammatical features of the target genres through query experience in a given corpus. Learners are given a chance to observe the same linguistic feature occurring in different contexts, thereby creating a rich contextual environment for its acquisition (see Figure 1 for a display of concordancing). It has the advantages of facilitating multilingual learners' lexicogrammatical development [23], promoting meta-linguistic awareness of discipline-appropriate expressions [24] and developing long-term autonomous language learning via corpus tools [25]. Currently, prior investigations have been largely limited to learners' development of word- and phrase-level grammatical features [26], the potential to teach larger chunks of linguistic units (e.g., reporting clause) remains to be explored.



	File	Left Context	Hit	Right Context
21	JAM_2019_005.txt	in FIGURE 1(a), andwc is the same width after confinement,	as shown	in FIGURE 1(c). This design is the same
22	JAM_2019_005.txt	thick computer numerical control (CNC) machined steel U-shaped clamps	as shown	in FIGURE 1(c) and 1(d). We choose only
23	JAM_2019_005.txt	side of the sample with a constant controlled velocity v	as shown	in FIGURE 1(e) and 1(f) from NUMBER to
24	JAM_2020_002.txt	a network of fibers that is produced from wood pulp	as shown	in FIGURE 1(a). The paper fibers have a
25	JBE_2020_002.txt	of eight New Zealand white male rabbits (average weight 3.9 kg),	as shown	in FIGURE 1(a). As in Ref. [16], the animals
26	JFE_2020_002.txt	is cut on the suction surface of the wing model (	as shown	in FIGURE 1(b)). The present SJ actuator is
27	JFE_2020_002.txt	of the chord and evenly distributed in the spanwise direction,	as shown	in FIGURE 1(b). In this work, in total 22
28	JHT_2020_005.txt	size of XXX , and then polished with a 1500 grit sandpaper,	as shown	in FIGURE 1(a). The fin samples with two
29	JMSE_2018_002....	types of surfaces, i.e., rough, sinusoidal, and random variations,	as shown	in FIGURE 1(a)–1(c), where the value of
30	JMSE_2018_004....	oud data, including flatness, thickness, circularity, cylindricity, and concentricity,	as shown	in FIGURE 1(b) and 1(c). In FIGURE 6, two
31	JMSE_2020_005....	to trigger the nanoparticle fusion in the water-deposited region,	as shown	in FIGURE 1(b). In our process, the temperature
32	JEGTP_2019_004...	related relations, and R8 and R9 are H2-dominated reactions.	As shown	in FIGURE 1(c), the entropy generation rate profile
33	JFE_2019_004.txt	repetitive arrangement with smaller cylinders surrounding them in the domain.	As shown	in FIGURE 1(a), the RVE height (H) is
34	JFE_2020_004.txt	repetitive arrangement with smaller cylinders surrounding them in the domain.	As shown	in FIGURE 1(a), the RVE height (H) is
35	JTm_2019_001.txt	gradients, etc., make the blade tip region face greater challenges.	As shown	in FIGURE 1(a), a significant thermomechanical damage occurs
36	JAM_2019_005.txt	the corresponding polarization in FIGURE 3(e)–3(h). When loaded slowly,	as shown	in FIGURE 3(a) and 3(e), the force–strain
37	JBE_2018_004.txt	than assumed, which results in better prediction of pressure drop,	as shown	in FIGURE 3(c), 3(f), and 3(i). However, the

Search Query ☑ Words ☐ Case ☐ Regex Results Set All hits Context Size 10 token(s)

as shown Start ☐ Adv Search

Figure 1 A concordance of "as shown" in Mechanical Engineering corpus

The Current Study

Motivated by a lack of scholarly attention to graduate-level multilingual writers in engineering and the potential of corpus-based writing instruction, the current study creates a language module in a form of tutoring intervention and assesses its effectiveness on four multilingual graduate students in Mechanical Engineering. Using a genre- and discipline-specific corpus consisting of 150 published empirical articles and 32 graduate students' manuscripts in Mechanical Engineering, the tutoring presents authentic and meaningful texts as linguistic reference. In so doing, the instructor can be saved from make discipline-inappropriate choices such as choosing an expression common in general academic English but infrequent in Mechanical Engineering. By comparing sentence-level features between expert and student writing, the tutoring derives four linguistic concepts, namely, Type of Clause, Effective Sentence Structure, Information Flow and Cohesion, and Grammatical Stance Expression. Each instructional unit starts with a lecture on one Linguistic Concept, followed by a Sentence Rewriting Activity and a guided Data Query Activity, and ends with a student-centered Self-assessment of the concept in their own writing. The assessment consists of Likert-scale questionnaires to gauge participants' quantitative evaluation of the tutoring and qualitative reflective presentations and interview data to probe their conceptual development of the linguistic concepts. In this paper, I aim to address the following two questions:

(1) How do participants perceive the design and the delivery of the tutoring sessions?

(2) How does participants' understanding of the tutoring relate to the objectives of the tutoring?

Tutoring Design: Preparation, teaching materials and goals

Preparation of linguistic concepts

The four linguistic concepts (Type of Clause, Effective Sentence Structure, Information Flow and Cohesion, and Grammatical Stance Expression) were chosen based on a corpus-based comparative analysis of published and student writing in Mechanical Engineering. This discipline-specific corpus consists of two components. The expert component consists of empirical articles published on 10 refereed journals under The American Society of Mechanical Engineers (ASME). Within each journal, 15 empirical studies (totaling 150 texts) were selected evenly across the years of 2018-2020, inclusive. The student component consists of 32 research article drafts (intended for publication) written by previous students of an existing Academic Engineering Writing course. The course instructor collected student writing over the past few years for her own research in engineering writing and agreed to share her data with the author of this paper.

After the compilation of the corpus, texts were syntactically parsed using Stanford PCFG Parser [27], which breaks clausal elements into hierarchical positions corresponding to their syntactic roles (e.g., NP, DT, PP). This is a widely circulated Natural Language Processing tool in Computational Linguistics and Corpus Linguistics because of its high reliability and operational ease. The syntactic parsing allows for an automatic extraction of complex sentences with different types of dependent (subordinate) clauses. The results were manually cleaned and classified into structural subtypes of clause according to the taxonomy in Table 1. Without going into much detail about the typological specification in English clause grammar, it should be noted here that the syntactic categories and structural subtypes were derived based on a careful consultation to grammar textbooks [28], [29], engineering writing textbooks [30], [31] and empirical studies of subordinate clauses in second language writing [32], [33].

By comparing the frequency of each structural subtype between published and student writing, the author detected categories that were significantly underused by students. This finding resulted in a detailed textual analysis of sentences within these categories to render some common linguistic themes that were later packaged into four sentence-level linguistic concepts: Type of Clauses, Effective Sentence Structure, Information Flow and Cohesion and Grammatical Stance Expression. Together with an introductory session on tutoring design and requirement and a summary session of students' reflective presentations, this tutoring features six 90-min lessons to help advanced multilingual writers improve their sentence-level communication.

Table 1 A syntactic taxonomy of subordinate clause in Mechanical Engineering

Types	**Subtypes**	**Examples from our corpus**
Finite clause		
Adverbial	Simple subordinator	***Although*** *these rules are widely practiced*, ...
	Complex subordinator	… ***so that*** *they are aligned with the rotor q-axis*.
Complement	Verb-	The results ***show that*** *the proposed approach is more*

	controlled	*efficient ...*
	Noun-controlled	... the ***possibility that*** *a people is the leader of this group*.
	Extraposed *it*	Thus, ***it is*** all the more ***imperative that*** *particle deposition and accumulation must be considered ...*
Relative	Relativizer-headed	..., the reaction zone narrows down as shown in Figure 4, ***which*** *further increases the temperature gradient*.
	No relativizer	However, the frequency range *the rig can explore* is limited (lower than 160 Hz).
Nonfinite clause		
Adverbial	*to*-clause	***To*** *study the results in the frequency domain*, ...
	Subordinator-free	However, ***based on*** *the particle pathlines* seen in Figure 7 ...
	Conjunction-headed	Furthermore, ***when*** *calculated at the group level*, ...
	Preposition-headed	***By*** *using the above definitions and assumptions*, ...
Complement	Noun-controlled	Our ***ability*** *to estimate cellular tractions and gel deformation* ...
	Verb-controlled	Care was taken ... to ***avoid*** *changing the relative position of the pump with respect to the camera.*
	Adjective-controlled	Furthermore, a disturbance observer is ***suitable*** *for estimating external forces*.
	Extraposed *it*	***It is important to*** *emphasize the differences between* ...
	Other	***To*** *describe any creature simultaneously as a reptile and as a dog* is a contradiction.
Relative	Participle	All ***calculations*** *involving heat flux* were corrected for radiation.
	to-clause	An alternate ***method*** *to examine the impact* ...

Teaching materials and design of each session

Drawing theoretical insights from Concept-Based Language Instruction (C-BLI; [34]), the intervention focused on developing coherent, high-quality conceptual knowledge that the students could appropriate and use in their engineering writing. C-BLI "begins with high-quality systematic knowledge" (e.g., linguistic concepts) and aims for learners to "appropriate them for use in concrete practical activity" [35, p. 80]. Accordingly, each tutoring begins with a lecture on one linguistic concept (20 mins), followed by a sentence rewriting activity (20 mins) where students practice their understanding of the concept by rewriting a paragraph selected from previous students' writing for clarity, and ends with a student-led self-exploration of this concept in their own writing (30 mins). In between Rewriting Activity and Self-assessment, a guided Data Query Activity (20 mins) was added to familiarize students with the extraction of each linguistic concept in the corpus and equip them with skills necessary for independent use of the corpus after the tutoring.

Each above-mentioned phase comes with a digital handout sharable via MS OneDrive (see Appendix for a sample handout). A Linguistic Concept handout includes a definition of the concept and its taxonomy similar in format with Table 1. A Sentence Rewriting Activity includes an instruction of the activity and an excerpt from previous students' writing in need of revision for clarity. A Data Query Activity includes step-by-step instruction on how to use AntConc 4.2.0 [36] to search for the concept in a given corpus. Lastly, a Self-assessment handout includes a task to reflect on the concept using two paragraphs of their own writing.

Goals for the tutoring

The tutoring, approved by the Institutional Review Board, was instructed by the author, a Ph.D. candidate in Applied Linguistics. Recruited participants committed their extracurricular time to exploring research articles in their field and identifying disciplinary practices of effective communication at sentence-level. To this end, the goals in this tutoring are quite ambitious and include leading students to:

1. Articulate effective linguistic choices to each other.
2. Identify the conventions of subordinate clause use in ME.
3. Apply corpus information to more effectively revising your own writing.

Data source and data collection

Entry and Exit Questionnaires

The Entry Questionnaire was administered before the initiation of the tutoring intervention. It collects participants' ethnical, educational background and academic writing experience. It also reports on their strength and weakness in writing for academic purposes. At the end of the tutoring, the Exit Questionnaire was administered which consists of two parts: 14 6-point Likert-scale question items and a short-text response question. The Likert scale ranges from "strongly disagree" (1 point) to "strongly agree" (6 points). Participants were asked to circle the number that mostly resembles their perception and evaluation of this tutoring. For the short response question, participants should write down the tutoring activity that they think is the most and the least helpful, and explain why.

Draft revisions

Revision is a problem-oriented process. A writer must be able to detect parts of a draft that are either inappropriate for the genre or could be done more effectively. Tracking the changes made at the sentence-level between two drafts of the same deliverable can help corroborate if participants paid attention to the learned concepts and were able to apply their knowledge intentionally and effectively. To acquire these textual data, participants, who were enrolled in an Academic Engineering Writing course at the time of this tutoring, were asked to share their course deliverables (two drafts of a literature review and two drafts of a full-length manuscript). All revisions made to the second draft of each document were kept through MS

Word “Track Changes” function by participants themselves. A subsequent linguistic comparison of the revisions identified meaningful changes that were raised in an interview with the participants at the end of the tutoring.

Reflective presentation videos

In Session 6 of the tutoring, students were given 10-15 minutes each to present their understanding of what they have learned and articulate the linguistic concepts and corpus techniques based on their own writing. They can either (a) select a few paragraphs and detect all four linguistic concepts or (b) select one linguistic concept and apply it to the entire draft. It offers an opportunity to practice their declarative knowledge of the four linguistic concepts, which will demonstrate their usefulness in disciplinary writing. This session was recorded via Zoom for the purpose of keeping all the details that may be useful later in the data analysis.

Semi-structured interviews

A semi-structured one-on-one interview was conducted virtually via Zoom to two consenting participants (Vando and Laoshi)[2] at the end of the tutoring. A set of questions about interviewees’ learning experience in and perception of the tutoring design and subordinate clause use in their writing were prepared beforehand, but additional questions emerged from interaction were followed. The interview started with some general questions regarding their expected learning outcome through tutoring, awareness of sentence structure in engineering writing, and evaluation towards the inclusion of a language module which focuses on teaching subordinate clause. It then captured their reasoning for making certain linguistic choices in their texts by sharing revisions in their deliverables and qualitative comments they made in questionnaires and reflective presentations.

Participants background

Three doctoral students (Vihaan, Shyla and Vando) were recruited from an existing graduate-level Academic Engineering Writing course in Mechanical Engineering taught by an engineering education specialist in a U.S. university. One doctoral student (Laoshi) was recruited from the author’s personal communication. All participants reported in their Entry Questionnaire that they had at least one first-author English publication. Yet, they had no prior academic writing instruction experience nor corpus experience. In reflecting on their strengths and weaknesses in writing for academic purposes, most reported on their unfamiliarity with skills for improving word choice and information flow. To help remedy this issue, they expected to learn from this tutoring how to maintain a smooth transition between paragraphs, how to write concisely, objectively, professionally and clearly, and how to avoid repetitions at the sentence level.

While Vihaan, Shyla and Vando had different specializations from Mechanical Engineering

[2] For participant privacy and confidentiality, the names have been anonymized.

(Table 2), they expressed familiarity with some journals that the author selected for the corpus and regarded Mechanical Engineering as a highly interdisciplinary field, where many related engineering fields contribute to the construction of its disciplinary knowledge. As for the types of deliverables, Vihaan was writing a draft for a conference, Vando was writing an extended abstract for a conference, Shyla was writing a literature review section of her dissertation, and Laoshi was writing his qualifying paper. Considering that the topic of sentence-level features applies to these various genres of academic writing and that the disciplinary focus on Mechanical Engineering research article writing was of interest to all participants, their learning outcomes and perceptions of this tutoring are reliable for assessing the effectiveness.

Table 2 Overview of tutoring participants

Participants	**Origin**	**Gender**	**Degree**	**Major**	**Strength**	**Weakness**
Vihaan	India	M	3rd Ph.D.	Aerospace	Comfortable burst writing	Wordy, not professional
Shyla	India	F	3rd Ph.D.	Industrial	Outline; Drafting and revising	Inflexible at major changes
Vando	Brazil	M	4th Ph.D.	Aerospace	Knowledge of the topic	English not L1; Technical terms
Laoshi	China	M	2nd Ph.D.	Mechanical	The logic of expression	Consistent ideas and content flow; sentence diversity

Effectiveness of the tutoring: Teaching sentence-level features

In this section, an overview of learners' perceptions of a language module that emphasizes subordinate clause use in discipline-specific writing will be presented. Based on respondents' perceptions and evaluation of this tutoring design (see Table 3), participants were receptive to studying linguistic concepts in general and along with corpus work, and they likewise valued the attention to sentence-level linguistic features broadly, as evidenced in the questionnaire results. Specifically, participants felt the instruction and some activities (Self-assessment and Sentence Rewriting Activities) facilitate learning (Q3, *M*=5.25, Q6, *M*=4.75 and Q8, *M*=5.25) and were most positive about the use of corpus to teach linguistic concepts in discipline-specific writing (Q4, *M*=5.5 and Q5, *M*=5). Additionally, they agreed that being proficient in (general) English was not sufficient for reaching the disciplinary expectation (Q14, *M*=5.5). However, the tutoring has not helped greatly with participants' query activity using corpus techniques (Q7, *M*=3.75 and Q9, *M*=3.75); hence, they were unable to use them independently outside of the class (Q11, *M*=1.75). The remainder of this section is organized around the three objectives of the tutoring design (Cf. *Goals for the tutoring*) using emerging

themes from the question items, respondents' short-text comments, draft revisions, reflective presentations and semi-structured interviews.

Table 3 Mean ratings of participant responses to the Exit Questionnaire

Question Item	**Mean Rating**
1. The concordance searching technique was easy to learn	4.75
2. It is easy to find answers to my writing questions using the corpus and AntConc	4
3. The tutor's instruction was helpful for learning the searching technique and analysis of the corpus	5.25
4. The corpus provides authentic and disciplinary-specific language materials	5.5
5. Using the corpus is helpful for learning the linguistic concepts and their functions in a text	5
6. The Sentence Rewriting Activity promotes my interest in writing and in-class learning	4.75
7. The Data Query Activity using AntConc is clear and helpful	3.75
8. The Self-assessment using my own writing is effective to practice the knowledge	5.25
9. I have some difficulty in analyzing linguistic concepts using AntConc	3.75
10. It is time-consuming to do corpus work activities during tutoring	2
11. I use the corpus when writing papers for other courses too	1.75
12. I use the linguistic concepts when writing papers for other courses too	4
13. After the tutoring, I learn how to write in a discipline-appropriate way at sentence level	4.5
14. To perform better in academic engineering writing requires more than being a proficient user of English	5.5

3.1 Articulate effective linguistic choices to each other

The C-BLI approach posits that for learners to internalize (i.e., they can use the new knowledge on their own) a scientific concept, it is important to have them verbalize in class. Through an instructor's mediation, learners should explain communicatively their understanding of the concept(s) they are learning to each other. In this spirit, the last tutoring session was devoted to individual presentations of their understanding and reflection of the four linguistic concepts and corpus techniques. It was found that every participant was capable of applying the linguistic concepts to their own writing (see Table 4). While Vihaan and Shyla chose to apply all four linguistic concepts to 2 paragraphs from their writing, Vando and Laoshi examined one linguistic concept in the entire draft.

Table 4 A summary of participants' reflective presentations

	#Sentences analyzed	Type of clause	Effective Sentence	Information Flow and	Grammatical Stance

			Structure	Cohesion	Expression
Vihaan	10	✓	✓	✓	✓
Shyla	8	✓	✓	✓	✓
Vando	51	✓	✓	×	×
Laoshi	20	✓	×	✓	×

To illustrate, Vando demonstrated his knowledge of the types of clauses by identifying them in one example sentence from his draft (see Figure 2). Interestingly, he added his reasoning underlying the construction of this sentence (the red-colored statement in the middle) to help the instructor evaluate the cognitive process of his writing. With the linguistic knowledge available to make sense of clause structures and their function in a text, Vando could verbally share his rationale behind the linguistic choices he made to compose his writing. It is an opportunity that was never made available before the tutoring because he did not develop a "conscious awareness" [37, p. 206] of such grammatical nuances in English-medium academic writing. More importantly, he also likened the linguistic concept with the "*technical side*" of his engineering work, showing his conceptual awareness, reasoning, and valuing of the intervention.

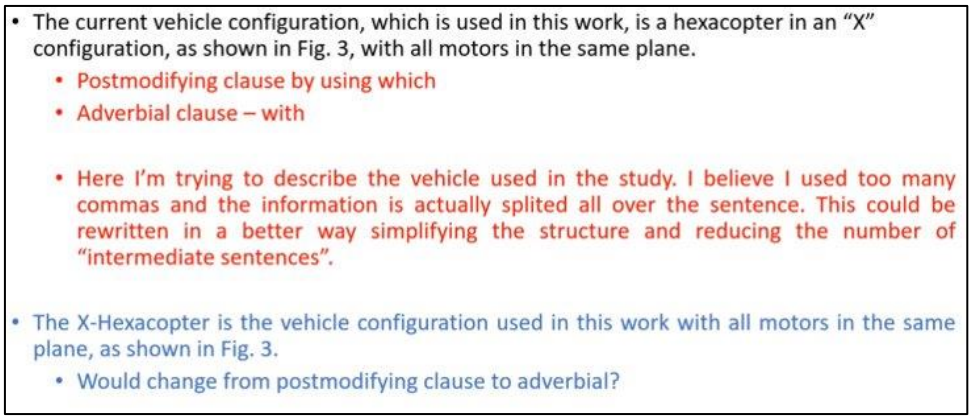


Figure 2 A screenshot of Vando's reflective presentation

> "*It [The concept] was not something I was really worried about when I first came here, at least not in my horizon, but as you move on, I definitely consider that it is an important topic, as important as your technical side.*" (Vando, interview)

Similarly, Shyla reflected on her past learning of English as a second language in India and pointed out that the linguistic concepts were insightful for writing but never came to her attention before. She highlighted the use of linguistic concepts to connect related ideas meaningfully into complex sentences, thereby making it easier for readers to follow her thought. This connection reflects her acute audience awareness as research article writing is

not only content-oriented but also dialogic and interactive.

> "*This tutoring session has introduced me to the linguistic concepts that I was not aware of because English is not my first language. […] Linguistic concepts will improve my writing skills because I can modulate multiple ideas to form a complex sentence which will help readers to better understand what I am trying to say.*" (Shyla, reflective presentation)

Her revision in the literature review deliverable substantiates what she meant by forming multiple pieces of ideational information into a complex sentence. The original version relies on the audience to understand that "*changes in the diameter of the pupil*" is equivalent to "*pupil dilation*". The revised version, on the other hand, uses a reduced relative clause (*modulated by …*) to condense two sentences with overlapping terminology, thus embracing a wider readership in addition to experts trained in Optics.

> "*Pupillometry is a technique to record changes in the diameter of the pupil. Pupil dilation is modulated by a part of the brain that controls physiological arousal and attention.*" (Shyla, first draft of literature review)
> "*Pupillometry is a technique to record* ***pupil dilation modulated by*** *a part of the brain that controls physiological arousal and attention.*" (Shyla, second draft of literature review; emphasis added)

However, one participant expressed difficulties with making sense of and internalizing the linguistic concepts. Laoshi, in his short-text response to the Exit Questionnaire, indicated that the linguistic concept was a hard and abstract knowledge and there were still not enough examples for him to absorb the concept. When asked about why the concepts were hard, he resembled the teaching of the concepts to that of his past English education in China, where a pedagogical focus was placed on rote memorization. Despite his successful articulation of Information Flow and Cohesion in his reflective presentation, his critical comments cautioned the unpacking of an abstract concept may require more definitional clarification and instructional support.

> "*It was very much like cramming. I have to absorb large numbers of abstract concepts in a short time span*." (Laoshi, interview)

The difficulty in learning an abstract linguistic knowledge was echoed in Vando's interview, where he talked about his awareness of grammatical stance expressions in English writing and yet his struggle to consciously use these expressions. From a Vygotskian perspective, this dissonance that he was experiencing with English stance expressions could open the space for further development provided that appropriate mediation is aimed at his Zone of Proximal Development of the concept. Such difficulty among multilingual writers is pervasive across ages, tasks and proficiency levels because they are not exposed to the same kind of linguacultural environment during learning as their English-native peers. Without an ability to notice linguistic features in writing and reading, multilingual writers are slow, if not

impossible, to pick up these linguistic cues and apply them to their own composition. One solution to address this is to provide them with explicit instruction on linguistic knowledge, of which this tutoring is an example.

> "*The stance expressions are the most difficult concept for me to understand. I know I use them, I know they exist, but I cannot connect these dots.*" (Vando, interview)

3.2 Identify the conventions of subordinate clause use in Mechanical Engineering

The intent of a genre- and discipline-specific corpus is to surface disciplinary conventions by situating linguistic findings within a discipline-specific context. Every example used in Linguistic Concept, every excerpt used in Sentence Rewriting Activity and every data query performed in Data Query Activity were derived from authentic texts of a single discipline. This preparation consolidates participants' confidence in learning from the experts in the same field rather than from writing experts in general. The latter has received some resistance from the learner's side for giving discipline-inappropriate feedback (Waring, 2005). Also, by restricting the genre to empirical research articles, the tutoring orients fittingly to participants' need to publish in refereed journals during their doctoral studies.

In this respect, participants in this tutoring were appreciative of using authentic and relevant examples from Mechanical Engineering research articles and able to detect some rules of appropriate subordination. Vando summarized in his reflective presentation the number of different subtypes of clauses used across subsections of a journal article (e.g., Introduction, Literature Review). The predominant use of complement clauses in Introduction alone may not mean much to a disciplinary writer, but complement clauses are most effective in constructing an authorial stance to project personal viewpoint and attitude towards a statement. In Ex. (1), Vihaan used an extraposed *it* complement clause, denoting his viewpoint of the "*increasing use of vision-based techniques on drones*" as a pressing limitation. Vando's use of a verb-controlled complement clause in Ex. (2) reports his interpretation of a major finding from a previous study. Both are useful in writing Introduction because its rhetorical expectation involves a critical review of previous research. The choice of an adjective or verb controlling a complement clause reveals a writer's stance towards the source of information he/she is citing as negative, neutral or positive. Likewise, if Vando went a step further to probing into the textual functions realized by relative and adverbial clauses, it would be very likely for him to find connections between clause use and rhetorical expectations of each subsection.

> "*Complement clauses were used more often in Introduction; [Relative] clauses were used more often in the Methodology/Results sections; Adverbial clauses were all over the place.*" (Vando, reflective presentation)

Ex. (1). With the increasing use of vision-based techniques on drones, *it is **necessary** to address these limitations* [39]. (Vihaan, second draft of literature review)

Ex. (2). By investigating rotor-to-rotor interactions, [4] ***found** that the thrust coefficient is not*

affected by the separation distance, but the thrust fluctuations are heavily dependent on it, increasing as the separation length is decreased. (Vando, second draft of full-length manuscript)

Laoshi, in his reflective presentation, shared his understanding of literature review in writing for publication purposes. He found the process analogous to peeling an onion: you find a research problem and review previous solutions to that problem, then you repeat the cycle until you reach the core problem to be addressed in the current paper. In doing so, a good information flow should be maintained throughout the passage. By taking advantage of four strategies to keep the information flow, Laoshi showed how he used linking adverbial clauses to revise the original draft (see Figure 3). In the original version, readers would wonder what "*molding techniques*" are and why they are introduced here. In the revision, the adverbial clause of purpose (*to improve the accuracy of cross-section*) denotes the reason why "*molding techniques*" can help address the problem stated in the preceding sentence, thereby saving readers' time and effort to figure out the logical connection by themselves.

"*In Literature Review, sometimes we just found the issue, and then propose or use a way to deal with that issue. And a new issue came out, we just found another way to deal with this new issue. So the problem is we need to use some* ***linking adverbials to keep the information flow***." (Laoshi, reflective presentation; emphasis added)

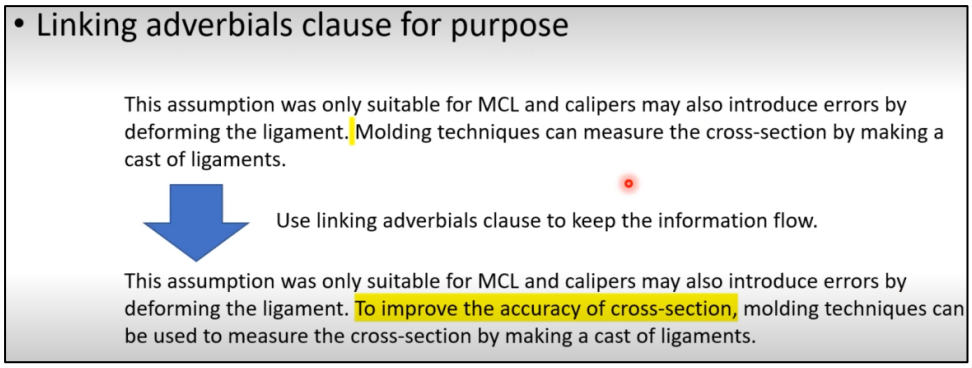


Figure 3 A screenshot of Laoshi's reflective presentation

Besides benefiting from writing and revising his own paper, Laoshi brought up his recent progress in reading others' work. He described how he was able to not just learn the technical knowledge of other researchers but also their writing style. Equipped with linguistic knowledge at sentence level, Laoshi can detect which type of clause was used to accomplish what textual function. As reading accumulates, he made available a great number of sentence structures for him to use in his future writing to enrich sentence diversity. This finding echoes the forgoing discussion of developing meta-linguistic awareness in multilingual writers, showing that a substantial increase in learners' linguistic resources hinges on their ability to identify them in a text. The tutoring provides pedagogic materials and activities conducive to the development of such ability.

"*After tutoring, I pay some attention to and learn from other writers' sentence*

construction when reading articles, especially how to avoid repetition of the same structure." (Laoshi, interview)

Vihaan and Shyla, on the other hand, didn't explicitly share their writing and research experience regarding conventions of subordinate clause use in Mechanical Engineering, but are in general optimistic of the usefulness to learn sentence structures in a discipline-specific corpus.

"*[The concepts] will be used to improve sentence structure and use effective linking words with proper emphasis on grammatical stance.*" (Vihaan, reflective presentation)
"*Corpus tool was insightful. It's a very quick way of knowing how researchers write in your field, what kind of sentence structures they use, which verbs and adjectives and writing styles are preferred.*" (Shyla, reflective presentation)

3.3 Apply corpus information to more effectively revising your own writing

Providing discipline-specific materials for learners to practice on is just one benefit of corpus-based writing instruction. The tutoring also expects participants to develop some basic query skills to extract sentence-level features using AntConc and grow into using corpus techniques for future writing tasks. Therefore, by way of assessment, one has to question if participants found extracting sentence structures using corpus techniques meaningful and they were confident to use corpus tools independently after tutoring. Their comments reveal that participants were not consistently in favor of or against using corpus techniques based on their varied engagement in Data Query Activities. Vihaan and Shyla found corpus to be useful for their writing only in broadstrokes. It is not clear what queries were useful and what were not.

"*Corpus can be an effective tool in identifying writing patterns.*" (Vihaan, exit questionnaire)
"*Corpus tool was really insightful and will improve my writing skills.*" (Shyla, reflective presentation)

Whereas Vando and Laoshi shared their experience using AntConc and the corpus to search for certain words. Particularly, Laoshi was able to use the corpus to validate for discipline-appropriateness when he detected in his writing stance marked by profuse use of the passivized construction. He found that published writing indeed chose a personal pronoun over passive voice frequently to report procedural specifics and significant findings. This self-exploration resonates with the stance of this paper—it is about harnessing appropriateness of sentence mechanics in a discipline, not about surface-level grammatical correctness.

"*Corpus is useful for checking word choice.*" (Vando, interview)
"*Previously, I chose a very objective stance towards my academic writing, where passive construction is the preferred style. During tutoring, I tried searching we or*

passive -ed in the corpus to see if it is appropriate." (Laoshi, interview)

However, the possibility of teaching learners to use corpus techniques to extract sentence-level grammatical features, such as the four linguistic concepts, is not sufficiently supported by the current study. While the step-by-step instructions in Data Query Activity handouts (see Appendix for a sample task) were generally straightforward, participants nevertheless found querying to be difficult or disorienting. For example, Vihaan confused the purpose of data queries using AntConc as discovering some "right" patterns to be adopted. It seems to him that queries selected for each linguistic concept failed to facilitate his understanding in a discipline-specific context. On the other hand, Vando stressed the importance of sufficient preparation for dealing with tasks involving a new tool. Instead of having participants watch a video tutorial of AntConc's basic functionalities, he suggested that 1-2 weeks of hands-on training might be more realistic. Laoshi similarly pointed out the time constraint to learn fully the functionalities of AntConc query syntax that eventually discouraged him from working independently after the tutoring.

"*While we were searching for words or phrases, we did not come to any conclusion as to the best practices to be followed or the type of writing that we must adopt based on the corpus investigation.*" (Vihaan, exit questionnaire)
"*You need to learn the tool really well. I can only do very simple queries. Or I have to go to manuals and tutorials to learn how to use that more deeply.*" (Vando, interview)
"*The wildcard functions and the limited time for teaching how to use AntConc made it difficult for me to perform the search by myself.*" (Laoshi, interview)

Conclusion

In this paper, I have described how a corpus-based writing tutoring intervention to teach sentence-level features in Mechanical Engineering can have a positive effect on graduate-level multilingual writers' composing and revising experience. All participants were grateful for analyzing disciplinary texts through a linguistic lens that not only helped them revise more effectively but read others' work with a fine-grained perspective. Serving as a language module flexible for an existing writing or content course, this tutoring accomplishes mainly two objectives: (1) it successfully promoted internalization of abstract linguistic knowledge to four participants to the extent that they were able to articulate their understanding of each concept relative to their own writing; (2) it showcased salient sentence-level conventions in Mechanical Engineering that they were not aware of before. The potential of corpus-based writing instruction to develop independent post-intervention query of sentence-level features using corpus tools is not fully understood in this study, despite that some participants were confident in using corpus to improve their writing in the future. To really expand the potential, a modified design is underway that will collect direct observation data such as screen recordings of participants' interaction with the corpus tools and query logs of their input outside of tutoring. Alternatively, it is possible to gauge the effectiveness of the tutoring more reliably by adopting an experimental design such that recruited participants' end-of-term papers can be compared to that of non-participants.

The takeaways for engineering faculties and engineering writing researchers are that: (1) A discipline-specific corpus can be pedagogically meaningful for creating writing course materials (see Conrad [38] for a corpus-based material development in Civil Engineering) because of its authenticity and rich contextual environment. (2) The four sentence-level linguistic concepts can be studied unassisted or given as a linguistic resource to multilingual writers struggling to maintain a coherent and logical sentence connection. Students can refer to the effective function and its linguistic example in the digital handouts whenever they are writing for research purposes. (3) This tutoring had a fifth participant, who speaks English as a native language. It was found that she developed some subconscious-level awareness of using different types of clauses to construct a coherent passage despite the difficulty of articulating the linguistic forms (e.g., clause types). Granted more feedback from English-native participants, the instructional materials can be expanded beyond teaching multilingual writers. English-native writers probably have no concerns about grammaticality in their writing, they nevertheless have to learn to write about their scientific knowledge in discipline-appropriate ways.

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Appendix: A Sample Handout of an Instructional Unit

Linguistic Concept: Information flow and cohesion

Effective writing makes it easy for readers to understand the writer's intended meaning. This is an especially important factor in engineering, where accurate, precise information is crucial.

A cohesive text is one where the language and content that a writer uses work together to

convey a clear message to the reader.
In English written communication, one of the most important ways to facilitate readers' understanding is to initiate a clause with given or background information and ends with new information, known as **old-new information flow**, so that readers could progress smoothly from the preceding sentence to the next without the risk of being "thrown off the cliff".

Four effective ways to accomplish cohesion in engineering writing

1. Repetition

→ Currently, most of the studies for DEP phenomenon are focused on Newtonian fluid. However, many common **fluids** of interest in the microfluidic field are **viscoelastic**. The **viscoelastic fluid** exhibits a mixture of both the viscous and the elastic behavior under strain.

→ Heat transfer and fluid flow by **natural convection** inside enclosures have attracted the attention of researchers because of its vast applications in industry and environment. Ho et al. [8] studied the **natural convection** of water–AmultilingualO3 nanofluids filled in three sizes of vertically square enclosures.

2. A dependent clause + independent clause

→ Recently, **microscale** two-phase flow in microchannel **heat exchangers** has drawn the attention of researchers due to its large surface area to volume ratios and high heat transfer coefficient (HTC). In order to identify the macro-to-**microscale** threshold for channels in **heat exchangers**, some criteria have been proposed.

→ Again because of high field frequency of magnetism, **all tiny particles** began to line up as a chain form along the magnetic field direction. When number of **such particles** gets improved in the chain, thermal energy distributes.

3. Dummy-*it* clause with old subject + new object

→ **Variables** considered at very different times are unlikely to form part of the same subproblem because their interactions could not then easily be considered and their values determined together. Still, it is possible that **variables** that a design team discussed concurrently are not in the same subproblem.

→ Salvage cost of **machines** is assumed to be 1% of the purchase cost [13]. In this case study, it is assumed that two **machines** are of modular architecture (i.e., MDR) and eight machines have integrated (nonmodular) architecture.

4. This/These + signaling nouns

→ This unintended large radial gap in the prototype created difficulties in modeling the flow and made it difficult to accurately match the experimental results with the optimized design. Despite **this problem**, the tooth tip leakages in the prototype do not significantly affect the meshing process of the gears where the variable timing principle of the VD-EGP occurs.

→ Unlike cement activated by water, alkaline forms aluminosilicate gels that do not absorb water while hardening, and **activates** geopolymers. This **activation** will cause less volume reduction and shrinkage for geopolymer samples.

Exception: If one uses logical connectors such as *however*, *on the contrary*, new information is placed before known information to show contrast.

Sentence Rewriting Activity

Task: Turn on Track Changes and Revise the text using old-to-new information flow
The global hearing aids market was valued at USD 4.5 billion in 2015 and is projected to grow with a CAGR of 4.3% over the forecast period. A middle ear implant is a hearing device that picks up sounds with a sound processor / audio processor that sits on the head, which converts the sounds into mechanical stimulation of the ossicles of the middle ear. It should be considered that most of the current hearing aids and implants just imply microphones as sensors for processing the coming sound which is located in an external housing and have some huge side effects such as discomfort, impractical be used during physical activities and sleeping due to heavy, detachment, break or lost, cannot be used under water, and mentally suffering due to social stigma. Noise is another drawback of available hearing aid devices. Our proposed device which can totally implant in the middle ear can overcome those restrictions and limitations mentioned above.

Data Query Activity

This time, we use the POS-tagged expert journal article corpus
The myth of un/attended *this* in engineering writing
What textbooks say: No stand-alone *this* to avoid vague reference.
What does the corpus of expert writing say? Perform the search by yourself. What do you find about un/attended *this* in expert writing?
For unattended *this*, how is it being used? What typical verb pattern do you observe?

1. Open the ME_FULL_TAG database (150 POS-tagged expert journal articles)
2. Check 'Case'
3. Input 'This_ DT ** [V*,MD]' into the search box
4. Run 'Start'

For attended *this*, what nouns usually collocate with it? What does it tell you?

1. Open the ME_FULL_TAG database (150 POS-tagged expert journal articles)
2. Check 'Case'
3. Input 'This_ DT ** N* ** [V*,MD]' into the search box
4. Run 'Start'

Self-assessment

Select two paragraphs from your own writing and perform a manual analysis of the cohesive devices used (e.g., repetition, linking words, pronouns, signaling nouns, old to new information structure). **Please**

(1) **Provide a very brief summary**

(2) **Select a few sentences with clause-level features and reflect on why they may have been written in that form** (i.e., what type of clause was used? Why were the clauses positioned as such? Was the old-new information flow understandable? Was this a cohesive text overall?)