Supplementive Participle Clauses in Science Journal Papers by Korean Graduate Students: A Corpus-based Study for Pedagogical Purposes

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This corpus-based study analyzes how supplementive participle clauses are used in science journal papers written for publication by Korean graduate students. Supplementive participle clauses help ensure syntactic sophistication and textual variety, but they cause difficulty to non-native speakers of English due to their diverse uses and structures and an unclear semantic relation between the main clause and the participle clause. With this concern in mind, this research uses 166 science and engineering journal articles written by Korean graduate students to investigate the frequency of supplementive participle clauses, as well as the supplementive participle clause structures and verb types used in them. Results show that this linguistic feature is used in Korean graduate students' papers much less than in those published in internationally recognized journals such as *Cell* and *Physical Review Letters* and that the verbs used in Korean students' papers lack variety. It is also found that dangling participle clauses are very often used and seem acceptable in written discourse in the science and engineering community. Pedagogical suggestions are provided to help Korean graduate students or EFL learners acquire supplementive participle clauses and use them appropriately.

Keywords: supplementive participle clauses, science journal papers, teaching EAP/ESP writing, corpus-based study

Background to the Study

The necessity for English for Academic Purposes (EAP) instruction has been increasingly recognized in Korean tertiary education since the implementation of English-medium instruction in the 1990s. In accordance with the trend of teaching content courses in English, universities in the country are actively pursuing EAP-oriented courses, and research (Hwang, 2002; Kim, 2015; Lee, 2009; Lee, 2014) has been conducted on the theoretical foundation of EAP, new curricula, and the results thereof. EAP, a subcategory of English for Specific Purposes (Dudley-Evans & St. John, 1998), differs from English for General Purposes, in that an EAP curriculum meets the specific needs of classes, has its own content, and includes specific grammar, vocabulary, and other aspects. Science and engineering, medical science, and business have been the major areas to which an EAP curriculum could apply. In the Korean higher education context, as science and engineering fields have gained more momentum, the need to develop EAP courses is greater than ever. Of the skills to be taught in an EAP curriculum, academic writing has recently received more attention as the pressure on Korean academics to publish their research results in reputable English journals has mounted due to fierce competition among Korean universities. This has led to a spike in demand for academic writing courses geared to writing at graduate and post-graduate levels. The age old academic cliché "publish or perish" resonates as loudly as ever in Korea, particularly in science and engineering fields.

Writing journal papers for publication, however, requires extra work and time from graduate students and professors in the science and engineering sectors of Korea, compared to their native English speaking counterparts. EAP related research indicates that academic writing is the primary source of difficulty for non-native English speakers (Hyland, 1997; Littlewood & Liu, 1996). Cho (2009) also found that graduate students and faculty members of a science and engineering university in Korea felt that they were at a disadvantage when publishing papers, in comparison with native English

speaking scholars. The situation holds true in other countries where English is learned and taught as a second or foreign language. J. Flowerdew's two articles (1999a, 1999b) both dealt with the disadvantages non-native English speaking scholars in Hong Kong had experienced when writing and publishing their research. Curry and Lillis (2004), Li (2006), and Li and Flowerdew (2007) examined writing practices of non-native speaking scholars; Curry and Lillis (2004) presented non-native speaking researchers' efforts in publishing their research for different target communities; Li (2006) examined a Chinese doctoral student's writing practices and negotiations for publishing her work; and Li and Flowerdew (2007) have suggested editorial services to non-native speaking scholars to help publish their research findings. Much research has followed with the same rationale in several countries such as Poland (Duszak & Lewkowicz, 2008), Venezuela (Salager-Meyer, 2008), Sudan (El Malik & Nesi, 2008), and Italy (Giannoni, 2008), reporting that researchers working in an EFL context were at a disadvantage compared to their native-speaking counterparts and those working in English speaking countries. In addition, inadequate English proficiency and training in paper writing for publication of graduate students, which may require proofreading and editing processes for their journal papers, would lead to delays in paper publication and decrease the chances of their papers being published. Some graduate students who had published papers in English journals mentioned that journal reviewers commented on their English and suggested obtaining editing and proofreading services from professional editors (Cho, 2009).

Thus, demand has increased for EFL practitioners and English teaching faculty to train graduate students with proper teaching materials for publication purposes. The supply for such instruction, however, has yet to catch up with this demand. Cargill, O'Connor, and Li (2012) addressed the mismatch between science and technology education on the one hand, and English teaching on the other. Their proposed solution is EAP-oriented and corpus-driven English approaches. Part of this task is to investigate and analyze graduate students' journal papers composed for publication, and to suggest ways to improve their academic writing skills, focusing on linguistic

features of the English language. This is because linguistic features such as sentence structure, grammar and vocabulary are known to cause more difficulty to non-native speaking scholars of English than meta-linguistic ones such as overall organization and paragraph structure (Casanave & Hubbard, 1992; Cho, 2009; Dong, 1998). Investigating characteristics of sentence structure and grammar unique to scientific prose and findings from the research will help young scholars in an EFL environment write better and more efficiently. Some research has been conducted to identify features of English in science journals: diachronic evolution of referential behavior in medical articles (Salager-Meyer, 1999), signaling nouns in a written biology corpus (J. Flowerdew, 2003), construction of stance through nouns followed by *that* in the disciplines of international relations and materials sciences (Charles, 2007a), verbs in reporting clauses used in citations of international relations and materials science (Charles, 2006), word frequency and distribution used in medical research article corpus (Chen & Ge, 2007), and the use of participial and relative clauses in two representative science journals*, namely *Cell* and *Physical Review Letters* (Cho & Kim, 2009).

The research above, however, analyzes papers published in academic journals, and is limited in determining the characteristics of the writings of a specific group of researchers. Thus, this research aims to look into journal papers written by graduate students researching at a research-centered university in Korea. It focuses on their use of supplementive participle clauses, which could ensure textual variety and syntactic sophistication, but are hard to use correctly and effectively by non-native speakers of English, particularly Korean students, due to their unique forms and the striking differences between English and Korean.

Literature Review

Supplementive Participle Clauses

Adverbial participle clauses of English are considered to be one of the most prominent features of academic writing due to their function of ensuring stylistic proficiency and an integrated, compact style (Granger, 1997) and due to their syntactic sophistication and versatility (Kameen, 1983). For example, sentence (1) below illustrates how a sentence with an adverbial participle clause ensures stylistic proficiency and a compact style by avoiding the use of 'and' and 'so' as in compound sentences.

> (1) The high cost of the new therapy for lung cancer has caused an economic burden to patients, <u>eliminating</u> their opportunity to get treatments.

The stylistic proficiency and syntactic sophistication from adopting adverbial participle clauses in academic writing, however, cannot be well utilized by non-native speakers of English. Granger, based on a corpus analysis of adverbial participle clauses in academic English writing, found that non-native speakers of English use them much less than native speakers and claimed that this underuse could lead to a stylistic deficiency in non-native speakers' writing. She analyzed two sets of corpora, one consisting of about 45,000 words of native speakers and the other of about the same size of non-native speakers, and discovered that non-native speakers of English used adverbial participles half as frequently as native speakers. What makes non-native speakers use fewer participle clauses, in particular, supplementive participle clauses (Quirk, Greenbaum, Leech, & Svartvik, 1985) or detached participles (Thompson, 1983) is that they are interpreted in diverse ways due to the absence of a subordinator in the participle clause. Without a subordinator, the semantic relation of the main clause and participle clause is blurred and likely to be interpreted differently and variously, without regard to the writer's intention.

Kortmann (1995) presented nineteen different interpretations of inter-clausal semantic relations of supplementive participle clauses, with the highest frequency of addition/accompanying circumstance (15.4%), simultaneity (14.4%), exemplification/specification (13.5%), cause (12.9%), anteriority (8.6%), and result (7.4%). This diversity could render non-native speakers hesitant to use supplementive participle clauses in their writing. In addition, the structure of supplementive participle clauses, which uses a comma after the main clause, before the participle clause, or right after the subject of the main clause, may lead non-native speakers to avoid using them. This could contribute to their underuse of such clauses, compared to native speakers or proficient non-native speakers of English. In Korean, for example, sentence-final supplementive participle clauses are not allowed; only sentence-initial participle clauses are acceptable. In English, both sentence-initial supplementive participle clauses as in sentence (2) and sentence-final supplementive participle clauses as in sentence (3) are allowed.

(2) <u>Investigating</u> the previous research carefully, they could have a better understanding of the underlying assumption of the theory.

(3) They finally had a better understanding of the underlying assumption of the theory, <u>achieving</u> unexpected research outcomes.

Sentence (3) should be stated by adding a conjunction like 'and' and a complete sentence or compound verb phrase as shown in sentence (4) below:

(4) They finally had a better understanding of the underlying assumption of the theory and achieved unexpected research outcomes.

Celce-Murcia and Larsen-Freeman (1983) pointed out that supplementive participle clauses are problematic for non-native speakers and even native speakers of English due to the rule that the subject of the main clause is assumed to be the same as that of the participle clause. If not, the participle is considered to be a dangling modifier or dangling participle and grammatically

inappropriate. Biber, Johansson, Leech, Conrad, and Finegan (1999) stated that if the subject of the main clause differs from that of the participle clause, the semantic connection between them is difficult or impossible to determine, as in this example:

(5) Doing the same experiments several times, the findings were finally confirmed.

Reading the sentence, readers assume that the subject of the main clause is an animate subject such as 'scientists' or 'the group'; however, with 'findings' as the subject, the sentence is likely to be misinterpreted. In the final supplementive participle clause also, the subject of the main clause is assumed to be identical to that of the participle clause, as in this example:

(6) The researchers delved back through the original literature describing the 29 sites, checking the accuracy of claims for the locations being 12,800 years old. (http://united877.rssing.com/chan-13731591/all_p164.html)

In the sentence, 'the researchers' functioning as the subject of the main clause is also the subject of the participle clause starting with 'checking,' which leads to the natural interpretation of the sentence.

The use of a consistent subject in both the main and supplementive participle clauses, however, is not often observed in published science papers. Cho and Kim (2009) found that about 95% of the subjects of sentence-final supplementive participle clauses in papers published in *Cell*, one of the representative journals in life science, do not correspond to that of the main clause, as in the following:

(7) Global DNA methylation patterns were reset, and the treated cells were endowed with a capacity to differentiate into a number of different lineages that remained capable of inducing tumors in vivo, suggesting a dominance of oncogenic alterations over a nonmalignant epigenetic state in this setting. (*Cell* Volume 157, Issue 3, p. 526, April 2014.)

In the sentence, the subject of the participle clause starting with 'suggesting' does not coincide with the subjects of the main clause, 'Global DNA methylation patterns,' and 'the treated cells.' Rather, the assumed subject of the participle clause is the experimental process or findings stated in the main clause, which belongs to the case of a dangling participle clause. The next sentence shows a similar example:

(8) In the former case, a 70 kD a protein was found to bind selectively to immunoglobul in heavy chains prior to their association with light chains, <u>indicating</u> once again a protein-protein interaction, herepotentially facilitating oligomeric assembly (Haas and Wabl, 1983). (*Cell* Volume 157, Issue 2, p. 286, April 2014)

The subject of the main clause 'a 70 kD a protein' does not serve as the subject of the participle clause starting with 'indicating.' Rather, the finding stated in the main clause is assumed to be the subject of the supplementive participle clause.

The frequency of supplementive or detached participle clauses varies, depending on the type of texts and the language proficiency of writers. Thompson (1983) analyzed the frequency of detached participle clauses with regard to text types and found that highly depictive texts such as a detailed historical account (74 instances per 10,000 words), a novel (62 instances), and a travel narrative (52 instances) show a far higher frequency than less depictive texts such as a pharmacology textbook (5 instances), an essay on biology (8.5 instances), a philosophical essay on natural science (9.0 instances), a biographical narrative of an artist (11.0 instances), an informative historical narrative on food (14.7 instances), and a book on literary criticism (18.9 instances). Cho and Kim (2009) investigated the frequency of supplementive participle clauses in two representative science journals, namely *Cell* and *Physical Review Letters* and reported that about six out of every 100 sentences of *Cell* papers contain supplementive participle clauses and four out of every 100 sentences of *Physical Review Letters* have supplementive participle clauses.

The frequencies based on the number of sentences can be expressed as follows: 27 instances per 10,000 words for *Cell* and 17 per 10,000 words for *Physical Review Letters* based on the total of 2,138 occurrences from the 778,337-word *Cell* corpus and 617 occurrences from the 348,002-word *Physical Review Letters* corpus. The difference in frequency is due to the fact that *Cell*, a journal in the field of life science, is more depictive and descriptive than *Physical Review Letters,* a journal consisting of papers from physics, chemistry, and some engineering fields. The frequency of supplementive participle clauses found in the journal papers, 27 instances for *Cell* and 17 instances for *Physical Review Letters*, turned out to be much higher than in a pharmacology textbook (5 instances) and an essay on biology (8.5 instances) in Thompson (1983). It must be noted that Thompson's investigation was based on one source for each text type, while Cho and Kim (2009) analyzed a total of 300 papers published in the two journals.

Along with the text types, the language proficiency of writers and whether they are native-speakers also determines the occurrence of supplementive participle clauses, as found by Granger (1997). 67 instances of supplementive participle clauses were found in the native speaker corpus of approximately 45,000-word, and 41 instances in a corpus of similar size collected from advanced ESL learners, which shows a statistically meaningful difference of $p < .01$. Native speakers employed 15 instances and non-native speakers nine instances of this linguistic feature, per 10,000 words. This frequency is much lower than the frequency found in *Cell* and *Physical Review Letters*, as reported in Cho and Kim (2009).

Corpus-based Research for Pedagogical Purposes in the Field of ESP/EAP

In the fields of ESP/EAP, corpus-based research for pedagogical purposes has long gained attention, as findings from a massive volume of authentic corpus data contribute to the investigation of distinctive linguistic features of certain genres (Flowerdew, 2002) and can serve as the basis for developing

dictionaries, grammar books and course materials (J. Flowerdew, 2012). This attention has made it possible for several books on the issue to be published recently: *New Trends in Corpora and Language Learning* (2010) by Frankenberg-Garcia, Flowerdew and Aston; *Corpus-based Studies in Language Use, Language Learning, and Language Documentation* (2011) by Newman, Baayen and Rice; and *Corpora and Language Education* (2012) by L. Flowerdew. All these books, as their titles indicate, aim to show how corpora are used in the learning and teaching of language. Before the advent of these books, Gavioli (2005) also published a book entitled *Exploring Corpora for ESP Learning*.

As Flowerdew (2013) put it, corpora for pedagogical purposes could have an impact on reference works such as dictionaries and the study of grammar. Lee and Swales (2006), for example, showed how corpora helped non-native speaking doctoral students in America self-learn and understand some features of English grammar such as usages of the definite article, participial phrases and reporting verbs. Their study clearly presented the possibility of corpora being used as an effective tool for teaching English to non-native speaking students, even replacing native speakers when learning some grammatical features of the English language. Hafner and Candlin (2007) also demonstrated how specialized law corpora could be used as an aid to writing assignments given to novice lawyers. The study reported that 21% and 40% of the students used the corpora provided to them when doing their legal writing tasks in the first and second years of their study, respectively. This implies that the students became accustomed to using corpora and recognized their benefits as time passed. In an effort to offset the limits of discourse analysis research and corpus-based research and to adopt them together for pedagogical purposes, Charles (2007b) investigated how an awareness of rhetorical functions of English texts aided international students and researchers in understanding them in corpus data. She claimed that instead of offering discourse and corpus work separately, providing a theoretical background first with examples from texts and then corpus data can contribute to an effective and quick understanding of rhetorical patterns of English texts. In a similar context,

Charles (2010) showed how corpus data could be employed to teach lexicogrammatical features as well as discourse patterns of writing in large scale mixed-discipline EAP writing classes. The study concurred with the previous study, in that corpus-based teaching materials provide a systematic approach to the teaching of EAP/ESP writing. Chang and Guo (2011) showed how corpora could be used to develop genre-specific teaching materials for students in Taiwan. Their research stood out as they applied the developed teaching materials to actual classrooms and reported the results with students' feedback.

In contrast to the afore-mentioned studies adopting native speakers' corpora, Flowerdew (2001) showed how learner corpora could be used for the development of EAP materials in an EFL context like Hong Kong. Using small learner corpora collected from the Hong Kong University of Science and Technology, she found that non-native speakers often differed from native speakers when using verb+noun collocational patterns and some discourse features such as 'then.' She suggested that these findings should be considered when developing materials for EAP. Gilquin, Granger, and Paquot (2007) also discussed the possibility of utilizing learner corpora for the learning and teaching of EAP writing. They claimed that learner corpora helped identify differences between native speakers and non-native speakers, such as the frequency of 'really,' 'of course,' and 'absolutely,' the position of 'however,' the usage of 'though,' etc. They suggested these differences should be taken into account when developing EAP materials for non-native speakers, advocating for the potential of learner corpora utilized for pedagogical purposes.

Corpus-based research in EAP/ESP fields has contributed much to the identification of specific linguistic and discoursal features of English writing, compensating for the limits of the genre-based approach, and has shown its wide potential for the teaching and learning of English. However, much of the research conducted so far has mainly been based on pre-existing native speaker corpora, which is bound to have limits when applied to teaching English to a specific group of non-native speakers. As Krishnamurthy and Kosem (2007) noted, the EAP corpora currently available do not meet the various, specific

needs of EAP practitioners and researchers due to the lack of customized corpora. Research findings from learner corpora, combined with native speaker corpora, could make significant contributions to the teaching of EAP writing for non-native speakers.

Research Questions

With these concerns in mind, this research is designed to investigate how supplementive participle clauses are used in science papers written for publication by Korean graduate students working in an EFL context, compared to those used in papers of prestigious science journals such as *Cell* and *Physical Review Letters*. *Cell* is a leading science journal which publishes research primarily related to biology and biochemistry. Research combined with engineering fields such as chemical engineering and mechanical engineering is published in *Cell*. The journal has a high impact factor of 32.232 as of 2014, which attracts scientists and researchers from around the world to publish their findings. *Physical Review Letters* is considered a prominent science and engineering journal for physics, materials science and engineering, electrical engineering, and computer science. The impact factor of the journal has been higher than 7.5 for the last five years, suggesting that this is the target journal for many scientists and engineers. Papers published in *Cell* and *Physical Review Letters* cover many fields of science and engineering.

Stylistically, the two journals differ. Papers in *Cell* are more akin to humanities and social sciences papers, which are verbal-oriented, while those in *Physical Review Letters* feature more equations, figures, and graphs, which require less exposition. This difference extends to supplementive participle clause use. That these two journals cover many fields of science and engineering and show different ways to explain research results has led them to be chosen as reference corpora for comparison with the manuscripts written by Korean science and engineering graduate students.

The research questions are detailed as follows:

1) How frequently are supplementive participle clauses used in science journal papers written for publication by Korean graduate students?
2) Which supplementive participle clause structures are used and which verbs are used in them?

Research Methods

Corpus Collected and Ways to Count Supplementive Participle Clauses

The corpus for the study was collected through the Language Education Center of a research-oriented university in Korea, whose main missions are to teach English to graduate students and to proofread papers written for publication by its graduate students and faculty members, and through research labs of the university. A total of 166 manuscripts were used to construct the corpus for the study. The manuscripts consist of 44 papers from materials science and engineering, 30 from electrical engineering, 25 from mechanical engineering, 16 from industrial engineering, 14 from chemical engineering, 13 from computer science and engineering, 8 from life science, 6 from chemistry, 6 from environmental engineering, and 4 from physics.

Counting supplementive participle clauses and identifying verbs used were performed manually and cross-checked by researchers. When counting the number of words in a paper, only those used in complete sentences were counted. Words in the titles, figure captions, graphs and references were excluded.

Descriptive Data for Papers Analyzed

TABLE 1
Descriptive Data for Papers Analyzed

	n
Papers analyzed	166
Total words	553,609
Total sentences	24,004
Average words per paper	3,325
Average sentences per paper	145
Average words per sentence	23
Instances of supplementive participle clauses	676

Table 1 shows the total number of words and sentences of the papers analyzed, average words per paper, average sentences per paper, average words per sentence and instances of supplementive participle clauses. The average words used per paper was 3,325; the average number of sentences per paper was 145; and the average number of words per sentence was 23. A total of 676 instances of supplementive participle clauses were identified.

Results

Frequency of Supplementive Participle Clauses

Out of a total of 24,004 sentences used in 166 papers, 676 instances of supplementive participle clauses were identified; about 2.8 sentences out of 100 adopted the structure. This rate is much lower than in *Cell* and *Physical Review Letters*, with 6.1 instances and 3.9 instances per 100 sentences, respectively (Cho & Kim, 2009). The low frequency of supplementive participle clauses is largely attributable to the fact that 36 papers out of 166 did not contain them at all, and 78 papers showed only one to five instances. Table 2 presents the counts of supplementive participle clauses used in each paper by frequency.

TABLE 2
Frequency of Supplementive Participle Clauses in Each Paper

Frequency	*n* of Papers	Frequency	*n* of Papers	Frequency	*n* of Papers	Frequency	*n* of Papers
0	36	5	10	10	4	15	2
1	19	6	11	11	5	16	1
2	22	7	8	12	2	19	1
3	15	8	6	13	2	20	1
4	12	9	7	14	2	Total	166

The 676 instances of supplementive participle clauses were then categorized into groups in terms of their positions in a sentence: *Main Clause, V+ing (active sentence-final supplementive clauses, FSC-active); V+ing, Main Clause (active sentence-initial supplementive clauses, ISC-active); V+ed, Main Clause (passive sentence-initial supplementive clauses, ISC-passive); Main Clause, V+ed (passive sentence-final supplementive clauses, FSC-passive); Subject, V+ed, Clause (passive sentence-middle supplementive clauses, MSC-passive)*; and *Subject, V+ing, Clause (active sentence-middle supplementive clauses, MSC-active)*. Table 3 shows the frequency of each type of supplementive participle clauses.

TABLE 3
Frequency of Supplementive Participle Clause Types

Supplementive Participle Clause Types	The Corpus
FSC-active	350 (52%)
ISC-active	126 (19%)
ISC-passive	102 (15%)
FSC-passive	43 (6%)
MSC-passive	34 (5%)
MSC-active	21 (3%)
Total	676 (100%)

Note. FSC-active: active sentence-final supplementive clauses; ISC-active: active sentence-initial supplementive clauses; ISC-passive: passive sentence-initial supplementive clauses; FSC-passive: passive sentence-final supplementive clauses; MSC-passive: passive sentence-middle supplementive clauses; MSC-active: active sentence-middle supplementive clauses

Out of the six types of supplementive participle clauses, the FSC-active type accounts for the highest frequency, 52%. This is probably because the authors are familiar with the structure through reading other journals or have learned about the structure and its functions in composition classes. The structure is the most frequently used in other journal papers with a frequency of 82.4% in *Cell* and 64.8% in *Physical Review Letters* (Cho & Kim, 2009). The structure well represents the causal relations between the main clause and participle clause. In many cases, in scientific writing, the main clause includes experimental processes and findings while the participle clause presents meanings, suggestions, implications, and interpretations through the verbs used in the participle clause. In this regard, the structure is effective in logically connecting the main clause and participle clause and serves as a substitute for 'and,' imparting syntactic sophistication and textual variety, as in sentence (9):

    (9)   For the RD, RSS of basal slip (RSS_{ba}) was zero, <u>meaning</u> that basal slip was inactive in this loading direction. (*P 112, Materials Science and Engineering) (*P 112 is a paper number)

Next, the structure of ISC-active accounts for 19% of all the cases of supplementive participle clauses, e.g.:

    (10) <u>Using</u> our assumption for L_{eff} matching for different value, L_{ext} is increased by ~ 3 nm per 1-nm increment of. (P 126, Electrical Engineering)

This structure is relatively easy to construct due to its simple composition of *V+ing* in the initial position of a sentence and the straightforward semantic relation between the participle clause and main clause. The participle clause serves as the cause of a given event or it describes an occasion happening before the main clause. In the example above, the participle clause functions as a means of making the content stated in the main clause happen. The structure has a frequency of 13.1% in *Cell* and 31.4% in *Physical Review Letters*. Here it

must be noted that despite the high frequency of this structure, the variety of verbs used in the participle clause is quite limited; two verbs, 'use' and 'compare' account for 56% and 13% of all the verbs used in the structure, respectively.

The next structure, ISC-passive, comprises 15% of all the supplementive participle clauses investigated. The frequency is very high, compared with instances found in *Cell* and *Physical Review Letters*, which show only a frequency of 4.0% and 3.5%, respectively. This high frequency is because 96% of the structure comes from verbs such as 'based on' and 'compared to.' These participles are taught as fixed expressions to Korean students, rather than as a form of a supplementive participle clause. A typical example with the structure is presented below:

(11) <u>Based on</u> our 3D FDTD program, we analyzed the transmittance of a gold layer having the thickness of 20 nm and phase difference between waves before and after passing through the layer. (P 22, Computer Science and Engineering)

The next construction, FSC-passive, accounts for about 6% of all the cases of supplementive participle clauses used. Compared with ISC-passive, the structure adopts a variety of verbs, such as 'compared with,' 'followed by,' 'measured,' 'based on,' 'caused,' 'called,' 'evidenced,' etc.

(12) Figure 2 shows EB conversion as a function of TOS in EB disproportionation over a total of 13 medium-pore zeolites with different framework topologies, as well as over the large-pore zeolite H-Y, <u>measured</u> at 523 K and 5.2 h^{-1} WHSV. (P 158, Chemical Engineering)

The next two forms, MSC-passive and MSC-active, account for frequencies of 5% and 3%, respectively. These structures, in which the supplementive participle clauses are placed immediately after the subject of a sentence, help provide syntactic sophistication and variety to texts; however, the structure would not be easy for Korean students to form due to their use of two commas

and the clause's position after the subject, which are not allowed in Korean. Below are two representative examples of these structures:

(13) Then a condensation phenomenon, <u>combined with</u> a loss of two hydroxyl ions and one water molecule, lead to the transformation of $[Cu(OH)_4]^{2-}$ into CuO at room temperature. (P 123, Chemical Engineering)

(14) For these reasons, mass production of optically compensated bend (OCB) mode (π-cell), <u>showing</u> the fast response time and wide viewing angle than twisted nematic mode, has been limited. (P 103, Materials Science and Engineering)

Here it must be indicated that whether a comma should be used before 'combined' and 'showing' as in sentences (13) and (14) or whether the supplementive participle clauses used in the sentences are semantically appropriate depends on the writers' intention. The supplementive participle clauses in the sentences above aim to provide additional, second level information about the subjects of the main clause, 'a condensation phenomenon' in sentence (13) and 'mass production of optically compensated bend (OCB) mode (π-cell)' in sentence (14). Depending on the intention of writers, the commas could be omitted.

Dangling Participle Clauses

About 80% of FSC-active structures turned out to be dangling participle clauses in which the subject of the main clause does not correspond to that of the participle clause. Sentences (15) and (16) include a dangling participle clause.

(15) At high frequencies, interface trapping does not respond to small signal oscillation speed, <u>resulting in</u> less stretching out of the CV. (P 108, Electrical Engineering)

In sentence (15), the subject of the main clause, 'interface trapping,' is not identical to that of the participle clause starting with 'resulting in.' The whole main clause, or the fact that 'interface trapping does not respond to small signal oscillation speed' functions as the subject of the participle clause and leads to the outcome described in the participle clause, 'less stretching out of the CV.'

(16) The base-rate fallacy was not due to obscure causal models of task scenarios, <u>suggesting</u> that people can consider base rates in their judgment if class and case data are regarded as being equally relevant to problem solving. (P 140, Industrial Engineering)

Sentence (16) also exhibits the grammatical feature of a dangling participle clause. The finding stated in the main clause, not the subject of the main clause, 'suggests' the content mentioned in 'that' clause.

Here it must be noted that the verbs used in supplementive participle clauses, such as 'result in,' 'lead to,' 'indicate,' and 'suggest' contribute to the formation of dangling participle clauses, and most verbs used in the FSC-active structure help form dangling participle clauses. Table 5 below details the ten most frequently used verbs in the FSC-active structure.

Verbs Used in Supplementive Participle Clauses

Investigating verbs used in supplementive participle clauses and comparing them with those in papers in internationally recognized science journals could contribute to developing teaching materials for graduate students working in the fields of science and engineering of Korea. Thus, verbs used in different supplementive participle clause structures were counted and their characteristics were analyzed. Table 4 presents the top ten verbs used in supplementive participle clauses. Out of a total of 130 different verbs used in all 676 instances of supplementive participle clauses, 'use' accounts for 13.0%, followed by 'base (based on),' 'result in,' 'compare,' 'indicate,' 'lead,' and 'suggest.'

TABLE 4

Top Ten Verbs Used in Supplementive Participle Clauses

Standing	Verb Used	Frequency	Proportion (%)
1	use	88	13.0
2	base (based on)	85	12.6
3	result in	70	10.4
4	compare	49	7.2
5	indicate	39	5.8
6	lead	35	5.2
7	suggest	22	3.3
8	follow	15	2.2
9	correspond to	12	1.8
10	show	10	1.5

In the FSC-active structure, 81 different verbs were used. 'Result in' tops the list with a frequency of 20%, followed by 'indicate,' 'lead,' 'suggest,' 'use,' 'correspond to,' and others. Since the participle clause usually entails results or outcomes of an experiment stated in the main clause, or implications and meanings of an experiment process described in the main clause, it is taken for granted that the verbs quoted above draw a high frequency; however, it should be mentioned that 'result in' accounts for only about 5% of the frequency in both *Cell* and *Physical Review Letters*. In *Cell* verbs such as 'suggest' and 'indicate' occupy a higher frequency and in *Physical Review Letters* verbs such as 'lead to' and 'use' are more commonly used. In the variety of verbs employed, *Cell* and *Physical Review Letters* outnumber those used in the papers of this study, showing 181 and 123 different verbs, respectively. This implies that the variety of verbs is lacking in journal papers written by Korean graduate students.

TABLE 5
Top Ten Verbs Used in FSC-active Structure

Standing	Verb Used	Frequency	Proportion (%)
1	result in*	69	20.0
2	indicate*	38	11.0
3	lead to	35	10.0
4	suggest	22	6.0
5	use	15	4.0
6	correspond to*	8	2.0
7	reduce	8	2.0
8	show*	8	2.0
9	form	7	2.0
10	mean	7	2.0

Note. The frequency of the verbs with * is not the same as that in Table 4, as some of them are used in different supplementive participle clause structures.

In the ISC-active structure, two verbs, 'use' and 'compare,' account for about 69% of all verbs used in this supplementive participle clause, which also indicates a lack of variety.

TABLE 6
Top Ten Verbs Used in ISC-active Structure

Standing	Verb Used	Frequency	Proportion (%)
1	use	70	56.0
2	compare	16	13.0
3	apply	5	4.0
4	look	4	3.0
5	take	4	3.0
6	depend on	3	2.0
7	add	2	2.0
8	multiply	2	2.0
9	plug	2	2.0
10	substitute	2	2.0

The next structure, the ISC-passive, also shows a similar trend; two verbs, 'based on' and 'compared to,' account for 96% of the frequency and only seven different verbs were used. The high frequency of the two verbs is probably because they are regarded as fixed expressions by Korean students. In contrast, it should be stated that verbs such as 'inspired' and 'motivated,' which serve to illuminate the motivation of the research conducted, were used, although the frequency was only one instance, respectively. Table 7 summarizes the findings.

TABLE 7
Verbs Used in ISC-passive Structure

Standing	Verbs Used	Frequency	Proportion (%)
1	based on	76	75.0
2	compared to	21	21.0
3	depicted	1	1.0
4	followed	1	1.0
5	inspired	1	1.0
6	motivated	1	1.0
7	taken	1	1.0

In the FSC-passive structure, which ranked fourth in the frequency of supplementive participle types, the verbs 'compared with,' 'followed by,' and 'measured in' account for about 61% of all verbs. This finding also shows a limited use of verbs.

TABLE 8

Top Ten Verbs Used in FSC-passive Structure

Standing	Verb Used	Frequency	Proportion (%)
1	compared with	12	28.0
2	followed by	11	26.0
3	measured in	3	7.0
4	based on	2	5.0
5	caused	2	5.0
6	called	1	2.0
7	evidenced	1	2.0
8	expected	1	2.0
9	indicated	1	2.0
10	not shown	1	2.0

Tables 9 and 10 describe verbs used in the middle of a sentence. 'Based on,' 'called,' and 'induced' were the major verbs used in the MSC-passive structure, and 'correspond to,' 'depend on,' and 'show' were the major ones used in the MSC-active structure.

TABLE 9

Top Ten Verbs Used in MSC-passive Structure

Standing	Verb Used	Frequency	Proportion (%)
1	based on	7	21.0
2	called	6	18.0
3	induced	3	9.0
4	named	2	6.0
5	referred	2	6.0
6	calculated	1	3.0
7	combined with	1	3.0
8	composed	1	3.0
9	considered	1	3.0
10	defined	1	3.0

TABLE 10

Top Ten Verbs Used in MSC-active Structure

Standing	Verb Used	Frequency	Proportion (%)
1	correspond to	4	19.0
2	depend on	3	14.0
3	show	2	10.0
4	use	2	10.0
5	anneal	2	10.0
6	be	1	5.0
7	feature	1	5.0
8	have	1	5.0
9	originate	1	5.0
10	refer to	1	5.0

Discussion and Conclusion

This study, based on the corpus constructed from papers written for publication by science and engineering graduate students in Korea, aims to show how customized learner corpora could be developed and investigated for the pedagogical purpose of teaching supplementive participle clauses in science writing. Compared with pre-existing corpora, customized learner corpora can reveal unique features of a language, depending on the characteristics of the contributors. The analysis of the specific non-native corpora demonstrates different language uses, as reported by Gilquin et al. (2007). This study, in line with other learner and customized corpora, found some distinct features of supplementive participle clauses.

TABLE 11
Frequency of Supplementive Participle Clauses in Each Corpus Set

	The Corpus	*Cell*	*Physical Review Letters*
Average Words per Sentence	23 words	22 words	22 words
Frequency of supplementive participle clauses (per100 sentences)	2.8	6.1	3.9
Frequency of supplementive participle clauses (per10,000words)	12	27	17

Firstly, the frequency of supplementive participle clauses used in graduate students' papers is much less than those in *Cell* and *Physical Review Letters* papers. About 2.8 instances per one hundred sentences were identified in the corpus, while 6.1 instances and 3.9 instances per one hundred sentences were used in *Cell* and *Physical Review Letters*, respectively. The frequency per 10,000 words shows similar results: 12 instances in the corpus, 27 instances in *Cell*, and 17 instances in *Physical Review Letters.* Although the number of words in a sentence is about the same across the three different corpora of the study (23 words), *Cell* (22 words), and *Physical Review Letters* (22 words), the underuse of the supplementive participle clauses characterizes the Korean graduate student corpus. To statistically verify the mean difference of supplementive participle clauses of the three corpora, an ANOVA analysis was conducted. The results show that the means for the corpora are significantly different at the level of .001, implying that the frequency of supplementive participle clauses used in the Korean graduate student corpus is much lower than in the *Cell* and *Physical Review Letters* corpus. Table 12 shows the ANOVA results.

TABLE 12
ANOVA Results for Comparisons of the Three Corpora

Source	Sum of Sq.	df	Mean Sq.	F	Sig.
Corpora	2588.17	2	1279.09	205.31	.000
Error	2878.27	462	6230		
Type of SPC*	8410.78	1	8410.78	937.61	.000
Type of SPC X Corpora	4608.22	2	2304.11	256.86	.000
Error	4144.34	462	8.97		
Total	22627.78	929			

Note. SPC means supplementive participle clauses.

A post-hoc test, Fisher's LSD (Least Significant Difference), also was conducted to investigate the mean differences among the Korean writer corpus, *Cell* and *Physical Review Letters* corpus. The results show that there are statistically significant mean differences between the three corpora: *Cell* > *Physical Review Letters* > the Korean writer corpus (MSe = 6230, p < .05). The less frequent use of supplementive participle clauses in *Physical Review Letters,* compared to those in *Cell*, is probably attributable to its unique discourse style, which is more math-oriented than *Cell*. In contrast, *Cell* is more verbal-oriented, whose discourse style is fairly similar to that of humanities and social sciences journals.

It also should be mentioned that 36 out of a total of 166 papers (22%) in the corpus did not employ the grammatical feature at all, and 55% of the papers used less than three supplementive participle clauses. The overall underuse of supplementive participle clauses across the papers and their scanty use in each paper may be attributable to the paper authors' incomplete mastery of the grammatical feature. This conjecture appears to be valid when the mean difference of supplementive participle clauses between the corpus *and Physical Review Letters* corpus is considered. That this corpus and the *Physical Review Letters* corpus present a statistically significant mean difference implies that many Korean graduate students may not know how and in what context supplementive participle clauses are used. Or they may have a perception that

using supplementive participle clauses may not be appropriate for scientific writing, whose primary goal is to deliver content as accurately and simply as possible. Using a complicated sentence structure such as supplementive participle clauses may be perceived as running counter to the general principle of scientific writing. These conjectures, however, need to be verified as this study did not measure their awareness of the target form and general English proficiency.

Secondly, as to the position of the supplementive participle clauses, the findings of this study are generally in line with the ones found in *Cell* and *Physical Review Letters*. In all three sets of corpora, the FSC-active structure showed the highest frequency, followed by the ISC-active structure and the ISC-passive structure. The high frequency of the FSC-active structure is somewhat unexpected, as the structure is not allowed in the Korean language; its high frequency could be explained by graduate students' acquisition of the structure through reading journal papers and textbooks in their fields and other sources such as taking technical writing classes. Nonetheless, the ratio of the structure, 52%, falls short of that of *Cell*, which is 82.4%, and *Physical Review Letters*, which is 64.8%. ISC-active structure shows the second highest frequency across all three sets of corpora with a ratio of 19% in the Korean student corpus, 13.1% in *Cell* and 31.4% in *Physical Review Letters.*

Thirdly, the high frequency of dangling participle clauses in the FSC-active structure seems noteworthy. In the papers analyzed here about 80% of the FSC-active structure contains dangling participle clauses, in which the subject of the main clause does function as that of the participle clause. This finding was generally in agreement with other published science and engineering journal papers. About 95% of sentence-final supplementive participle clauses in *Cell* exhibited dangling participle clauses (Cho & Kim, 2009). In the sentences using dangling participle clauses, the subject of the main clause is mainly concerned with means of performing an experiment or experimental results, while the participle clause mostly presents results, implications, and suggestions for the experiment stated in the main clause, employing verbs such as 'resulting in,' 'leading to,' 'suggesting,' and 'indicating.' The dangling

participle clause, which is considered ungrammatical in a strict sense, is acceptable in science journal papers. This discrepancy with traditional grammar does not outweigh the fact that dangling participle clauses are acceptable and even favored in the discourse community of science and engineering.

In addition, for verbs used in the supplementive participle clauses, the graduate student corpus lacks diversity, compared to the *Cell* and *Physical Review Letters* corpus. In the student corpus, 130 different verbs were used in total, which is even fewer than the number of verbs used in just the FSC-active structure in the *Cell* corpus, 181. This represents a substantial disparity. Moreover, the two most frequently used verbs were 'use' and 'base (based on),' accounting for 25.6% of all types of verbs found in the corpus. This lack of diversity stands out in the ISC-passive construction, in which 'based on' and 'compared to' comprised 96% of verbs used in the structure. Also in the ISC-active construction, 'use' and 'compare' accounted for 56.0% and 13.0%, respectively. The lack of diversity in verbs used in the supplementive participle clause also could be analyzed in terms of the lack of diversity based on each individual paper. For example, Paper 30 used only one type of verb, 'based on' although five instances of the linguistic feature were employed. Also, Paper 77, in which four instances of supplementive participle clauses were used, had only one verb, 'based on.' In the papers with many occurrences of supplementive participle clauses such as in Papers 21 (10 occurrences), 87 (11 occurrences), 45 (13 occurrences), and 149 (15 occurrences), the diversity of verbs was also lacking, showing four different instances of the verbs in all four papers. For example, Paper 149 used 12 instances of 'resulting in,' one instance of 'leading to,' one instance of 'opening, 'and one instance of 'corresponding to.'

Lastly, the comma in the sentence-final supplementive participle clauses was missing in some papers. Paper 48 below provides a good example:

(17) On the other hand, the segregation of lithium to the grain boundary can make the LAGP samples less dense leading to low relative density. (P 48, Materials Science and Engineering)

In the sentence, a comma needs to be used before 'leading to,' the verb of the supplementive participle clause; however, it is missing. About ten papers out of a total of 166 had instances of missing commas. Although the occurrence rate of this error is not particularly high, it should be mentioned that the use of a comma in the sentence-final supplementive participle clause is the most prominent feature of the structure, and thus its absence of a comma may blur the distinction between the normal adverbial participle clause and the supplementive participle clause. A sentence without a comma in the sentence-final supplementive participle is considered to be "infelicitous" (Granger, 1997), which may be seen as a lack of English language proficiency of writers.

Pedagogical Implications

The findings of the research can lead directly to pedagogical suggestions and implications, one of the major goals of the research. Granted that supplementive participle clauses better ensure syntactic sophistication and textual variety, teaching their structures, frequency and functions is highly recommended for science and engineering graduate students. In particular, the sentence-final participle clause deserves to be taught with emphasis as its frequency found in this research falls short of that found in internationally recognized journals, and verbs used in these clauses lack variety. One reason for this lack of variety is that Korean students seemed to favor general verbs over specific ones. For example, Paper 149 used 12 instances of 'resulting in,' some of which could have been replaced by clearer and more specific verbs.

(18) First, the single crystalline ITO nano-branches act as direct conducting pathways for hole transport, <u>resulting in</u> charge balance between hole and electron. (P 149, Electrical Engineering)

Sentence (18) could have been rephrased as '..., <u>balancing</u> hole and electron charges,' by replacing the verb 'resulting in' with a more specific verb such as "balancing." Because choosing more suitable and specific verbs is challenging for non-native speakers of English, this aspect of lexical choice should be explicitly taught, particularly in scientific writing. One effective way to teach the linguistic feature is to choose journal articles showing the appropriate, moderate use of the structure in terms of the frequency and diverse verb uses, and present them along with a list of frequently used verbs found in the research conducted. As a concrete example, the top ten verbs found in the research and other research (Cho & Kim, 2009) could be a useful source for this task. The emphasis on the sentence-final supplementive participle clause, however, does not imply that other structures such as sentence-initial adverbial clauses can be ignored. Rather, it should be taught that the moderate use of sentence-initial supplementive participle clauses also impart textual sophistication and variety even to scientific writing. For example, sentence-initial supplementive participle clauses starting with 'motivated' and 'inspired,' which were found in the study, could serve as effective sentence structures to illuminate the semantic relations between the participle clause and main clause.

In addition, other means of ensuring syntactic sophistication and textual variety could be implemented to reduce the overuse of supplementive participle clauses. The overuse of these structures may contribute to impeding syntactic, and textual variety, contrary to their original purposes. A relative clause with 'which' followed by the comma could substitute for the sentence-final supplementive participle clause with the FSC-active structure, as in this example:

(19) Compared to this, the Zn2p peak in figure 3b shifted to higher binding energy after H_2S exposure, <u>which indicates</u> that Zn2p binding energy increased through chemical reaction of ZnO with H_2S. (P 128, Chemical Engineering)

In the papers analyzed for this study, 155 instances exhibited the above structure, which could replace sentence-final supplementive participle clauses. The balanced use of the two linguistic structures would make it possible to demonstrate more syntactic sophistication and variety of sentence structures, which would contribute to shortening the time for editing and proofreading papers written by non-native speaking scholars working in the fields of science and engineering.

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