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Review Article

A Review of Lexical Bundles in Research Articles across Hard Sciences Disciplines Including Medical Sciences

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Abstract

Background & Aims: The importance of "publish or perish" in academic contexts, especially for faculties and graduate students, is an undeniable problem because of its role in determining university achievement around the world. To deal with such problems, academic writers must be fluent in language repertoires (e.g., lexical bundles), which are an essential component of scholarly writing and necessary for creating publishable research articles (RAs).

Material & Methods: Hence, the present study reviews 85 empirical RAs that have been done to extract highly frequent 4-word lexical bundles (LBs) published between 2008 and 2021 in ISI and Scopus-indexed journals across various hard sciences disciplines including medical sciences. Additionally, it offers a list of the general academic four-word LBs in the various sections of hard sciences RAs that can be used as a reference list of general LBs for scholarly writing in hard sciences.

Results: The review revealed that in each discipline, the experts use discipline-specific bundles. The findings also revealed that academic writing structurally relies heavily on phrasal bundles and functionally on referential bundles.

Conclusion: The current study concludes that it is essential to explore disciplinary linguistic features such as LBs in academic writing to enhance academic success and RA literacy. The results may also be useful in developing appropriate educational materials and activities on LBs for academic writing in hard sciences such as medical sciences.

Keywords: English for Medical Purposes, Hard Sciences, Lexical Bundles, Research Articles

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Introduction

Individuals who speak English as a second language need to develop a high competence in it due mainly to the fact that it constitutes the most frequently used international language in academic and occupational settings. A number of researchers have stated that most universities prompt their students to publish their papers in quality journals owing to the impact of these publications on their international rank (1-3). Consequently, the researchers have experienced diverse difficulties due to the necessity of publishing their articles in the above-mentioned journals. As Belcher (2007) pointed out, the researchers' situation is further exacerbated because of the lack of access to important resources and the lack of peer support (4, 5).

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The development of writing skills in academic settings depends on the learners' ability to use the LBs in an efficacious way (6). Moreover, the learners' knowledge of second language vocabulary can provide information on their stage of writing ability development (7). It can be argued that the learners' capability to take advantage of LBs in their writing tasks has an advantageous impact on their ability to form discourse pieces that are characteristic of various scientific disciplines (8). LBs are regarded as the constitutes of academic texts that reflect the writers' competence in their relevant field of knowledge (9-11). This issue highlights the fact that the instructors who provide English for Specific Purposes (ESP) and English for Academic Purposes (EAP) students with writing instruction should provide their learners with adequate information on the LBs which are integral parts of the texts in their pertinent disciplines.

Literature Review

English for Medical Purposes and LBs:

As some researchers pointed out English for Medical Purposes (EMP) has been developed due mainly to the fact that the information on medicine-related professions has been widely disseminated (12). EMP refers to the field of knowledge that provides people with medicine-related jobs with English instruction. This field of knowledge makes an effort to deal with the unique English-related needs of professionals in medicine-related fields. Moreover, it endeavors to make these professionals familiar with the underlying topics in medicine-related fields. Lastly, it tries to enable these professionals to develop the specific English-related skills that are essential to their field (13). The relevant research has focused on the instruction of medical vocabulary since it fulfills a consequential role in medical texts. The medical students' knowledge of the aforementioned vocabulary items empowers them to express their intentions effectively in English and improves the comprehension of their sources that have been written in English. Furthermore, this kind of knowledge has a beneficial impact on the learners' understanding of the content of the lectures that are given in English (14). It can be argued that the medical students' lack of knowledge of the etymology of the medical vocabulary may hinder their understanding of various words in medicine-related texts (15). This issue highlights the fact that EMP instructors need to provide their learners with information on the morphology of medicine-related vocabulary in their relevant academic settings (16).

The concept of LB has fulfilled an important role in Applied Linguistics and EAP research since its development (6, 17, 18). LBs constitute an underlying aspect of communication and refer to the co-occurring sets of words whose co-occurrence frequency has been supported by statistical evidence (17, 19). In other words, LBs refer to the groups of words which are frequently used with each other and provide information on their users' social, academic, and occupational identity (e.g., *in the present study, it is possible that*) (20, 21).

The importance of LBs stems from their functions in the discourse of various academic fields (22-24). Biber et al. (1999) noted that LBs constitute 21% of academic texts (17). Moreover, as they noted, 17% of these LBs recur throughout these texts. This issue highlights the importance of LBs in the above-mentioned texts, shows that their appropriate use reflects the writes' expertise in their relevant field of knowledge and highlights their partnership in the relevant community of discourse (20, 22). Nonetheless, the multi-word structure of LBs tends to have a detrimental impact on language learners' acquisition and use of various LBs in their writing tasks (25-27). These difficulties stem from the learners' lack of knowledge about their relevant register and their

inability to use the pertinent words of their register in an appropriate way (28). As Hyland (2012) pointed out, the importance of LBs stems from the fact that they enable the writers to use the language accurately and fluently (29). Moreover, they highlight the fact that their users are experts in their relevant disciplines.

Biber et al. (2004) stated that LBs can be classified into four main categories including the LBs that involve noun phrases (e.g., *the results of this*), prepositional phrases (e.g., *in the present study*), verb phrases (e.g., *play a role in*), and dependent clauses (e.g., *it should be noted that*) (22). Consequently, LBs involve either clauses or phrases. As it is pointed out, LBs can be used to organize discourse (e.g., *on the other hand*), highlight stance (e.g., *were more likely to*), and demonstrate references (e.g., *there was no significant*) (22).

The research on LBs has become a major line of research in first and second language studies. Biber et al. (2009) pointed out that, the interest in LBs stems from their role in the learners' writing ability (30). Nonetheless, as Hyland (2012) stated, the relevant research studies of LBs have disregarded the examination of their discipline-related variability (31). For instance, the results of the study that was conducted by Cortes (2004) indicated that the types and functions of the LBs that were used in the fields of biology and history differed (22). Likewise, Hyland (2008) noted that many of the LBs were characteristic of specific fields and their forms and functions varied greatly from discipline to discipline (32). In this regard, based on their research of a sizeable corpus of spoken English, Simpson-Vlach and Ellis (2010) created a list of LBs that were employed in the hard and soft sciences (33). Similarly, Garboswski (2015) examined the functions of the LBs that were utilized in pharmacy-related textbooks and protocols (34). The results of this study highlighted the existence of differences between the above-mentioned texts due mainly to their topics.

In addition, the results of the study that was carried out by Durant (2017) highlighted the fact that the language learners' use of LBs was the most noticeable aspect of the variation among different fields of knowledge (35). Likewise, the findings of Kwary et al.'s (2017) study showed that the learners used the largest and the smallest numbers of LBs in the physical sciences and health sciences respectively (36).

Furthermore, Chen's (2019) study's findings demonstrated that advanced English language learners were competent in using a wide range of LBs when completing essay-writing tasks (37). Likewise, Yin and Li (2021) carried out a study to determine the formal and functional characteristics of the language learners' LBs in the fields of accounting and finance (38). The results of this study indicated that there were some overlaps and differences between the forms and functions of LBs in the above-mentioned fields.

Evidence suggests that LBs or subject-specific vocabulary have significant roles in evaluating students' academic writing (39) and promoting academic discourses (40, 41). Therefore, due to the formulaic structure of scholarly writing and the challenges learners have in employing these sequences effectively, learners need to be acquainted with the sequences accompanying the communicative functions of scholarly writing (٤٢). It would seem appropriate to publish an updated review given the rising use of bundles in RAs. Accordingly, the present study reviews the highly frequent four-word bundles in a variety of hard sciences fields including medical sciences.

The study made an effort to provide answers to the following query:

What is the most frequently employed list of the general academic four-word lexical bundles in hard sciences research articles?

Methodology

The search generated 100 empirical RAs that have

been done to extract top-frequency four-word LBs in a variety of hard-science fields. The collected RAs were published from 2008 to 2021. Selecting the articles were based on the following inclusion criteria: 1- they had to be investigating LBs in different sections of research articles of the hard sciences fields; 2- they were empirical studies; and 3- they adhered to Swales' (2004) IMRD framework including Introduction-Methods-Results-Discussion.

Different databases including Elsevier, John Benjamin's, Sage, Springer, Taylor & Francis, Oxford University Press, etc., comprised the sources of the RAs corpus (see Table 1 for a complete description of the corpus). To retrieve appropriate RAs, the main keywords "English for Medical Purposes", "hard sciences", "lexical bundles", and "research articles" were used. The articles were individually double-checked by two researchers. Following this, inter-rater reliability was determined and the results revealed 91% agreement between the two raters in terms of inclusion and exclusion criteria. Fifteen RAs were excluded and a final list of 85 RAs was prepared for the evaluation. This amount seemed reasonable given that we sought to analyze in depth a substantial number of high-quality empirical studies.

The last step was synthesizing findings: Finally, we synthesized our findings to answer our research question. This identified a list of the general academic 4-word LBs in the various sections of hard sciences RAs. We also discussed implications for teaching academic writing in hard sciences including medical sciences or for future research in this area.

Table 1. Description of the corpus

Publisher	Journal Title	No. of articles	Year
Elsevier	Journal of English for Academic Purposes	18	2008-2021
	English for Specific Purposes	16	2008-2021
John Benjamins	International Journal of Corpus Linguistics	7	2008-2021
Oxford University Press	Applied Linguistics	7	2008-2021
Sage	Language Teaching Research	6	2008-2021
	Sage Open	9	2008-2021
Springer	Educational Studies in Mathematics	3	2008-2021
	Journal of World Languages	5	2008-2021
Taylor & Francis	Language Studies		2008-2021
	Southern African Linguistics and Applied Language Studies	9	2008-2021
TESOL Asia (Australia) and the English Language Education Journal group	Asian ESP Journal	3	2008-2021
University of Murcia Press	International Journal of English Studies	2	2008-2021
Total		*85*	-

Results

The current study endeavored to determine the top-frequency general LBs across different hard-science disciplines to enable the syllabus designers to take advantage of them in the development of instructional materials (see Table 2) (22, 24, 34, 43-45). Additionally, it offered a list of the general academic 4-word bundles in the various sections of hard sciences RAs (24, 25, 34, 43, 46-48). (see Appendix A for the complete list of the LBs).

Table 2. The top 10 most frequent lexical bundles across different hard-science disciplines

Study	lexical bundles (Tokens)	discipline
Abdollahpour & Gholami (2018)	this study was to [220], of this study was [216], the aim of this [114], the purpose of this [107], aim of this study [100], purpose of this study [97], in this study we [62], the objective of this [58], study was to evaluate [54], objective of this study [53]	Medical sciences
Cortes (2004)	at the same time [144], in the absence of [111], the end of the [107], on the other hand [80], as a function of [88], as well as the [73], on the basis of [71], in the case of [62], at the end of [60], on the one hand [50]	Biology
Grabowski (2015)	the dose should be [434], with other medicinal products [392], ability to drive and [368], to drive and use [364], drive and use machines [362], date of first authorization [361], be used with caution [350], should be used with [320], dose should be reduced [319], every one or two [298]	English pharmaceutical texts
Hyland (2008a)	on the other hand, [726], at the same time [337], in the case of [334], the end of the [258], as well as the [253], at the end of [252], in terms of the [251], on the basis of [247], in the present study [225], is one of the [209]	Electrical engineering & microbiology and business & applied linguistics.
Jalilifar et al. (2017)	at the end of the[198], in the case of the [151], as a result of the [137], on the other hand the [134], on the basis of the [114], due to the fact that [108], one of the most important [102], it should be noted that [100], at the same time the [98]	Sciences (Agricultural science, General Medicine, Chemistry, Physics, and Computer science)
Qi & Pan (2020)	of this study was to [352], the aim of this 205, aim of this study 189, the primary outcome was [187], were randomly assigned to [145], the purpose of this [127], the primary endpoint was	Medical sciences

Study	lexical bundles (Tokens)	discipline
	117, were included in the [102], were more likely to [82], study was to investigate [71]	
Yin & Li (2021)	are more likely to [349], we find that the [229], we find that the [192], the extent to which [144], in table panel a [124], is consistent with the [115], results are consistent with [103], are less likely to [99], more likely to be [97], is positive and significant [95]	Biology

Note: The superscript numbers indicate the frequency of each bundle

As shown in Table 2, a few instances of four-word LBs are distributed across different disciplines (e.g., *as well as, at the end of*, *on the basis of*). This finding highlights the fact that, in each discipline, the experts utilize unique LBs due mainly to the fact that these LBs constitute a major aspect of their communicative competence in their relevant field (24).

Discussion

A bulk of studies have highlighted that various feature of the language are characteristic of specific fields of knowledge. The findings of these researches suggest that there is a need to make learners in various disciplines familiar with the relevant features of their discipline-specific discourse (24). As it is noted, the particular sequences of words in our produced language are related to our values and show our group membership (49). Likewise, other researchers pointed out that, our utilized LBs reflect our membership in certain discourse communities (50). Members of a given academic community use domain-specific LBs to create specialized discourse that is only understood by members of that community and may be difficult for members of other disciplinary domains to understand (48) .

It can be concluded that LBs vary from discipline to disciple in academic writing (25, 32, 51). Consequently, the hard sciences instructors have to make their learners aware of the differences among various disciplines in terms of their LBs and need to provide them with information on the most frequent LBs in their pertinent field of knowledge.

Clausal bundles, according to Biber et al. (1999), are composed of VP-based bundles that integrate significant clauses, while phrasal bundles are mainly comprised of NPs and PPs. Previous studies (25, 27, 30, 32, 52, 53) have provided evidence that discussion comprises a considerably higher proportion of clausal statements (e.g., *I want you to*), which are defining elements of conversations (30). On the other hand, a significant portion of the LBs in academic genre are phrasal such as *at the end of*, *on the basis of*. The findings of the current review article are in line with those of previous studies. It is argued that compressed phrasal bundles are more favored compared to elaborated clausal bundles in the academic genre since “they are more economical; they allow for faster, more efficient reading; they are equally comprehensible to the expert reader” (27). As their writing skills advance, writers are thought to switch from clausal to phrasal structures (27, 52). Higher proficiency research authors were shown to depend mainly on phrasal than clausal structures (54, 55).

Functional analysis of the corpus revealed that hard sciences RAs showed a strong preference for *referential* bundles than *stance expressions* and *discourse organizers* which is consistent with some previous

studies (20, 24, 25, 34, 50, 52). Biber et al. (2004) found that whereas academic writing and textbooks contain more *referential bundles* (e.g., *one of the most*), conversations typically rely on *stance bundles* (e.g., *I don't know what*). The reason for these discrepancies, according to Conrad and Biber (2005) (56), is that spoken language places more emphasis on interpersonal interactions while academic writings place a greater emphasis on conveying essentially factual information. Referential bundles serve an ideational purpose by assisting writers in organizing their experiences and choosing their points of view (25).

Our analysis demonstrates that a bulk of empirical studies have just descriptively investigated LBs in the academic genre. It is high time to convert these empirical studies into pedagogical activities through explicit genre-based instruction and engage learners in discipline-specific writing tasks to create field-specific genre literacy. Bundles are extremely challenging for L2 learners to learn (57), hence it is important to concentrate on and teach these sequences in academic writing classes.

The retrieved list of bundles can be used as a reference list of highly frequent general LBs when teaching academic writing, especially for novice researchers and graduate students in hard sciences, as well as resource developers and academic writing course instructors in EMP (22, 24, 34, 47, 48, 58). The extracted list of LBs in different hard and soft sciences can be seen as a crucial aspect of '*essayist literacy*' (59). We think that corpus-driven bundle lists will be useful for introducing novice students to the reading and writing of discipline-specific genre in hard sciences. The EAP community would be able to further adjust and enhance academic vocabulary teaching and learning with the use of these lists (60). Academic Writing instructors should instruct students to apply previously taught or encountered sequences of LBs again in subsequent speaking or writing tasks to promote their efficient retrieval (61). The review revealed that to date, numerous studies have been conducted on lists of discipline-specific LBs in various hard and soft sciences RAs, but no study has specifically focused on their instructions. Further research must be done, with an emphasis on teaching the list of LBs in EAP courses and assisting students in mastering both general and discipline-specific bundles.

Conclusion

This study strived to determine the top-frequency LBs in the articles of various fields of hard sciences including medical sciences. It also offered a list of the general academic 4-word lexical bundles in hard sciences RAs. The review of the related literature highlighted the fact that formulaic sequences constituted an integral part of academic writing. Furthermore, based on the results, the genre was a determining factor in the writers' use of LBs that were characteristic of their discipline(24). The EAP instructors should take account of the specific LBs in their relevant discipline and need to make their learners familiar with their discipline-specific vocabulary to help them to develop satisfactory academic writing competence (62).

A few limitations of this study should be pointed out and remedied in future studies. First, we only examined a limited number of hard-science disciplines' research articles, thus our findings cannot be generalized to other disciplines. Since there is a dearth of research in this area, lexical bundles in other fields deserve further study. Second, because our corpus only contained 85 RAs, its findings should be interpreted with caution, and more studies are required to support our findings.

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Conflict of interest

The authors declare no conflict of interest.

Data availability

The datasets during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Appendix A

List of the General Academic Four-word Lexical Bundles in Hard Sciences

Lexical bundles	Lexical bundles
aim of this study	this study was designed
for the treatment of	aim of the study
in this study we	in the absence of
objective of this study	study was to compare
of this study was	the end of the
purpose of this study	an increased risk of
study was to evaluate	is known about the
the aim of this	there were no differences
the objective of this	was significantly associated with
the purpose of this	during the follow up
this study was to	in the development of
was to evaluate the	in the present study
study was to investigate	the follow up period
of this study is	as well as the
study was to determine	in the presence of
this study is to	included in the study
there were no significant	long term follow up
the aim of the	more likely to be
in the control group	of the present study
was to investigate the	was no significant difference
study was to examine	were randomly assigned to
in the united states	compared with the control
were no significant differences	in a sample of
study was designed to	is one of the
was found to be	of this study were
little is known about	present study was to
this study aimed to	was to assess the
was to determine the	in this study the
were more likely to	is associated with a
of the study was	no significant difference in
the study was to	to evaluate the effectiveness
these results suggest that	this study were to
was to examine the	were not significantly different
no significant differences in	study was to assess
an important role in	the present study was

Lexical bundles	Lexical bundles
between the two groups	to be associated with
this study examined the	at the time of
at the end of	a function of the
has been shown to	a large number of
results a total of	a measure of the
there was no significant	a wide range of
these findings suggest that	a wide variety of
were included in the	an important role in
a function of the	an increase in the
a large number of	an order of magnitude
a measure of the	are likely to be
a wide range of	are more likely to
a wide variety of	as a consequence of
an important role in	as a function of
an increase in the	as a result of
an order of magnitude	as the number of
are likely to be	as well as the
are more likely to	at the beginning of
as a consequence of	at the end of
as a function of	at the same time
as a result of	at the time of
as the number of	at the university of
as well as the	be the result of
at the beginning of	can be used to
at the end of	did not differ significantly
at the same time	each of the three
at the time of	for each of the
at the university of	for the evolution of
be the result of	has been shown to
can be used to	have been shown to
did not differ significantly	in addition to the
each of the three	in contrast to the
for each of the	in each of the
for the evolution of	in the absence of
has been shown to	in the case of
have been shown to	in the context of
in addition to the	in the evolution of
in contrast to the	in the form of

Lexical bundles	Lexical bundles
in each of the	in the life cycle
in the absence of	in the number of
in the case of	in the presence of
in the context of	in the present study
in the evolution of	in the study area
in the form of	is a function of
in the life cycle	is consistent with the
in the number of	is likely to be
in the presence of	is the number of
in the present study	it is difficult to
in the study area	the relationship between the
is a function of	the relative importance of
is consistent with the	the rest of the
is likely to be	the results of the
is the number of	the shape of the
it is difficult to	the size of the
in the presence of	the slope of the
in the present study	the total number of
on the other hand	there is no evidence
the end of the	these results suggest that
is one of the	used in this study
at the end of	was found to be
it was found that	was positively correlated with
at the beginning of	with respect to the
as well as the	with the exception of
as a result of	with the number of
it is possible that	was associated with a
are shown in figure	further research is needed to
was found to be	the results of this study
be due to the	this is the first
in the case of	was not associated with
is shown in figure	these findings suggest that
the beginning of the	studies are needed to
the nature of the	is associated with a
the fact that the	our results suggest that
may be due to	these results suggest that
are summarised in table	can be used to

Lexical bundles	Lexical bundles
has been shown to	an increased risk of
an important role in	associated with an increased
at room temperature for	for the treatment of
at the same time	analyses were performed to
can be used to	in a ratio to
in the absence of	outcome measure was the
as shown in figure	were used to determine
with respect to the	masked to treatment assignment
used in this study	data were collected from
was added to the	in all patients who
a result of the	a cross-sectional study
in addition to the	a secondary analysis of
the quality of the	regression analysis was used
are listed in table	secondary end points included
is due to the	were used to evaluate
the presence of a	has the potential to
the results of the	our findings suggest that
was found in the	it is important to
were found to be	it is likely that
a wide range of	it is possible that
the effect of the	may be due to
the presence of the	more closely related to
to the presence of	not appear to be
was used as a	not significantly different from
as a result the	of the distribution of
have been shown to	of the effects of
in this study the	of the number of
is possible that the	of the relationship between
the beginning of the	of the variance in
the center of the	of the variation in
the course of the	on the basis of
the degree to which	on the evolution of
the depth of the	on the number of
the direct effects of	on the order of
the effect of the	on the other hand
the effects of the	one of the most
the end of the	play an important role
the extent to which	presence or absence of

Lexical bundles	Lexical bundles
the genetic basis of	similar to that of
the length of the	spatial and temporal variation
the magnitude of the	studies have shown that
the mean number of	that the number of
the mean of the	the average number of
the nature of the	the number of species
the number of individuals	the population dynamics of
we conducted a retrospective	the position of the
was used to identify	the probability that a
were included in this	the base of the
at the end of	in a number of
at a dose of	in the field of
was assessed using the	the central nervous system
years or older with	the most widely used
patients were randomized to	to determine whether the
was used to assess	To our knowledge, no
were used to assess	a central role in
we randomly assigned patients	associated with an increased
masked to treatment allocation	been associated with increased
the primary outcome was	Centers for Disease Control
were randomly assigned to	examined the effects of
the primary endpoint was	In a recent study
a retrospective cohort study	in patients treated with
little is known about the	in the United Kingdom
this study is to	investigated the effect of
analysis was used to	is thought to be
The aim of the	it is necessary to
aim of the present	mortality in patients with
study was to evaluate	of Health and Human
of this study were	of the most important
was to evaluate the	studies have focused on
study was to investigate	studies have suggested that
The objective of this	the degree to which
study was to assess	the relationship between the
have been associated with	the United States and
have been found to	with an increased risk
in the pathogenesis of	with the development of

Lexical bundles	Lexical bundles
is considered to be	a key role in
was to assess the	a leading cause of
study was to determine	a major cause of
been found to be	been shown to have
is the most common	cause of death in
The purpose of the	considered to be a
Goals of This Investigation	for Disease Control and
little is known about	However, little is known
objective of this study	in a group of
was to investigate the	in the oral cavity
in the management of	In this paper, we
in vitro and in	is believed to be
have been used to	is characterized by a
in the U.S	
is known about the	
It was hypothesized that	
number of studies have	
this study were to	
a number of studies	
is associated with increased	
related quality of life	
study was to compare	
a better understanding of	
also been shown to	
and the use of	
has been found to	
Health related quality of	
in the form of	
of morbidity and mortality	
of the most common	
study was to examine	