Graphics in Physics Research Articles

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INTRODUCTION

Academicians of different disciplines may have different ways of expressing academic content. Those from the humanistic fields may tend to be more verbose while those with a scientific bent may, by training as much as necessity, prefer to use other means of communications such as graphics and equations to convey data or findings. If different social networks do prefer different means of communicating, it is thus important for the ESL community to understand these means. An analysis of the way graphics are linked to the text will enable teachers and learners alike to understand how to do this effectively If the links can be summarized in equation form, these will become that much easier to teach and learn Such summarizations can also become part of a typology of scientific writing which may be developed in the future.

THEORETICAL FRAMEWORK

Swales (1992) sees the social network not as a community with material demographic or geographic substance but one that persists by instantiation and by engagement. In the words of Miller (1992), "it is constituted by its characteristic joint rhetorical actions, its genres of interaction, of getting things done " In other words, a social network is defined by shared actions and perceptions. Therefore, different networks must act and perceive things differently (Otherwise, they would be part of the same network.) In this context, language use is

"a socially accepted association among ways of using

> language, of thinking, feeling, believing, valuing, and of acting that can be used to identify oneself as a member of a socially meaningful group or "social network ... "
>
> (Gee 1990.143)

By this definition, language use is thus network specific, that is, different networks use language differently. Different networks will in turn perceive the same piece of discourse differently A piece of discourse that meets the precepts of a particular network will be accepted as good discourse by that particular network, but not necessarily by other networks. In this context, it is important for linguists to understand and describe how different networks communicate

OUTLINE OF STUDY

To achieve a clearer understanding of the way scientists communicate, this study proposes to investigate the use of one component of scientific writing, that is, graphics, such as figures, tables, diagrams, graphs and pictures in one type of scientific texts – Physics research articles – and to find out how these graphics are linked to the texts themselves. (Equations, as a formidable area of study in its own right, are not considered in this study) Texts are usually assumed to be largely linear but scientific texts seem to have a disproportionately large amount of graphics both in terms of number and physical space. The large amount of space devoted to graphics indicates that they could be a very important component of scientific writing and the cohesive devices used to link them to the linear text of the article must therefore also be crucial for any would-be scientific writer to master The ultimate objective of this study is to create models for writing these links. To these ends, this study poses four research questions.

1. How significant are graphics in scientific articles in terms of frequency of occurrence?
2. What are the distribution and functions of graphics in Physics research articles?
3. How are graphics linked to the text in Physics research articles?
4. How can the grammatical structures of these links be summarized in formulaic form?

RESEARCH METHOD

Thirteen scientific (Physics) journal articles totaling 44,341 words were examined. (To simplify data entry, every equation and formula is considered as one word symbolized by an *.) These articles were randomly selected on the basis of being among the first four articles of four randomly picked Physics journals (see Appendix). First, the amount of space devoted to graphics was measured and calculated as a percentage of total space taken up by the whole article. The amount of space given over to graphics gave a rough indication of the importance of graphics in this genre of writing. Next, the locations of the graphics within the texts were noted and these indicated the functions of the graphics themselves. Finally, the lemmas "figure(s)", "table(s)" and "graphs" were counted using the Longman Mini-Concordancer program. This gave an exact count of the number of times the tokens occurred.

All linguistic devices linking the graphics to the texts were examined and categorized. The different categories of cohesive devices were then analyzed for common grammatical structures. All collocations to the tokens were examined. The common grammatical structures were then distilled into formulaic form

RESULTS

1 Significance of graphics

Scientific writing is generally described as writing of high information density A significant number of journals limits each article to about five pages of print. Scientific authors are expected to condense their communication in just that amount of space and no more. Wise usage of space is therefore of paramount importance. Scientists often resort to non-linear texts such as figures and photographs, tables and equations as they can convey meanings far more economically than words. As can be seen in Table 1, this study bears this out. On the average, only 55% of a scientific article is devoted to linear texts. The remaining 45% is almost evenly divided between graphics and equations. As both are capable of communicating information in a far more condensed yet more comprehensible manner, the writers tend to replace a lot of linear texts with graphics.

The amount of physical space given over to figures and tables is very significant, ranging from a low of 9.55% to a high of

Table 1: Amount of space devoted to linear and non-linear texts in Physics articles

Name of Article*	Space utilized by		
	Figures and Tables	Equations	Linear Texts
AP1	20.96%	19.30%	59 74%
AP2	33.46%	20.45%	46.09%
AP3	26.14%	19.61%	54.25%
AP4	15.30%	26.55%	58.26%
CM2	14.45%	5.67%	79.88%
CM3	51 79%	0.00%	48.21%
CM4	13.70%	24.66%	61.64%
CJP1	11.24%	31 78%	56.98%
CJP3	9.55%	36 13%	54.32%
EJP3	18.62%	23.28%	58.10%
EJP4	34.42%	33.52%	32.06%
JMR3	22.47%	0.41%	77.12%
JMR4	43.36%	0.62%	23.82%
Average	24.27%	18.61%	54.65%

*Refer to appendix for key to names of articles.

51 79%. The average is 24.27% or almost one page out of four In conclusion, it is clear that graphics are a very important, if not the most important component of scientific writing, otherwise it would not have been given so much physical space.

2. *Location of graphics*

Graphics can be found in all parts of the articles. However, a look at Table 2 reveals that the use of graphics is concentrated in the results and method sections of the articles. Out of the 72 graphics employed in the 13 articles studied, 73.6% is used to describe the results of the experiments. Another 11 1% is used to clarify various aspects of the methods used. A mere 15.3% of the graphics is scattered in the introduction, theoretical framework

Table 2: Distribution of figures and tables in various sections of the research articles analyzed

Article	No.	Intro.	Theory	Method	Results	Conclusion
AP1	7	–	–	–	7	–
AP2*	10	1	1	4	3	–
AP3	6	1	–	1	4	
AP4	7	–	1	–	6	–
CM2	3	–	–	1	2	–
CM3*	5	–		–	7	–
CM4	4		–		4	–
CJP1	3	3	–	–	–	–
CJP3	6	1	–	1	4	–
EJP3	5	--	–	–	5	–
EJP4	2	–	1	–	1	–
JMR3	4	–	1	1	2	–
JMR4	10	–	–		8	2
Total	72	6	4	8	53	2

* Some graphics occurred outside the article proper, for example, in the appendices, and are not counted.

and conclusion parts of the articles We can safely conclude that graphics are mainly employed to describe the methods and results of experimentation in Physics research articles although this does not exclude their use elsewhere

3. *The links between graphics and linear texts*

Another indication of the importance of graphics is the frequent references to graphics in the article (see Table 3). On the average, there is one reference to some form of graphics every 155 words. The frequency of reference to graphics not only indicates the importance of graphics in these articles but also shows that linear and non-linear texts are strongly linked to make these articles unified pieces of discourse.

The linear and non-linear texts are linked in two ways - the captions and the references to the graphics within the texts

Table 3: Frequency of occurrence of lemmas referring to graphics

Token	Times occurred (%)		1 time per x words
Table	10	(3.8%)	4083
Graph(s)	10	(3.8%)	4083
Fig(ures)	227	(86.3%)	180
Diagram(s)	16	(6.1%)	2552
Total	263		(or once per 155 words)

3.1 Captions

The most important link is the captions of the graphics. Every graphic has a caption that explains what the graphic is showing. The structures of the captions are highly formulaic and therefore relatively simple to analyze. Captions consist of three parts, that is, the enumerator, the topic and the explanation

3.1(i) The enumerator

The enumerator is obligatory Every caption has one without fail. It numbers each graphic representation and allows easy reference of each The enumerator consists of one word-form of the lemma "Table" or "Figure" followed by an integer *n* and a full-stop, in this manner·

Table *n*.
Fig. *n*
Figure *n*.

The preferred lemma seems to be "figure" which has four forms. It occurs as the nouns *fig., figs*
72, 2, 141 and 12 times respectively. The lemma "figure" seems to be used as an umbrella term for all sorts of graphics. For example, "The diagram in figure 1 corresponds to this ..." (CM4). Here "figure" in the enumerator has clearly been expanded semantically to mean "diagram" since the diagram was labeled as a figure. Yet in the text, the author reverts to calling it a

diagram. Clearly, the semantic expansion does not apply to the text itself This clearly indicates the lemma "figure" is an indispensable part of the enumerator

There is also a clear tendency towards favoring the singular forms (see table 4) and this is born out when we examine in detail the frequency of occurrences of each form of the other three lemmas.

Table 4: Frequency of occurrences of word-forms referring to graphics

Word-forms	No. of occurrences	Word-forms	No. of occurrences
fig	72	table	10
figs.	2	graph	7
figure	141	diagram	13
figures	12	diagrams	3

The lemma "table" only occurs in the singular form. Similarly the singular forms of both "graph" and "diagram" are also widely used. This preponderance for the singular forms may have a very simple explanation Graphics are used precisely to present information in a very tightly condensed form. It would very likely overload the reader if he has to process the information in two or more graphics simultaneously Therefore, unless it is crucial (for making comparison, for example), authors would not refer to more than one graphic at a time to avoid overloading the readers with information To summarize, the enumerator is normally made up of the singular form of "Table" or "Figure" followed by an integer n and a full-stop In formuliac form,

$$Enumerator = (Fig. / Figure / Table + n + \ )$$

3.1(ii) The topic

Immediately after the enumerator is the topic. The topic serves to identify the graphics. Structurally, it always takes the form of a noun phrase with a head noun usually modified by at least one adjectival phrase, like:

Figure 1 Coordinates relative to a plane slab.
Figure 1 Coordinate system used in the analytical model.
Table 1. Lattice parameters (A) for NH4 VO3.

The head noun may be modified by multiple adjective phrases. For example,

Table 2. Pressure dependencies of the IR mode of NH4 VO3.
Figure 7 An equivalent circuit, with associated conductances and capacitances as shown, which can be used to represent the second term in equation (AI)

The modifying adjectival phrases serve to define as clearly as possible the parameters of the information contained in the graphics. The structure of the topic can be summed up as

Topic = {Noun phrase + nth Adjectival phrase(s)}

3.1(iii) The explanation

The third part is the explanation which is made up of one or more complete sentences providing explanations for details included in the graphics, for instance.

The arrow and normalization are as for figure 1
The pion kinetic energy is in the laboratory frame at a laboratory angle of 90' The oscillator parameter b=1 77fm and the uncertainty approximation is used. Also included is a comparison of the high-energy approximation (dotted line) to the uncertainty approximation (broken line) The theory is normalized to the data and a value of the oscillator parameter b=2.75fm is used for a 'larger' nucleus.

To a large extent, the explanation is optional. Authors may choose to omit it if they feel the graphics are self-explanatory.

3.2. Textual links of graphics

The second type of links between graphics and the linear texts are the references made in the linear texts themselves to these graphics. In the linear texts, the lemmas diagram, figure, graph and table are preceded as well as followed by certain words in very rigid patterns. The table below summarizes the preceding collocates.

Table 5: Words preceding "figure"

Words	Times occurred	% of total occurrences
in	87	38.33
(as) for	7	3.08
of	9	3.97
to	1	0.44
Total	104	45.82

Ignoring the single instance of "(According) to fig.", a total of 103 tokens (45%) of "figure" is immediately preceded by a preposition, typically "in". In a very few cases, these are preceded by "of" or "as for" or "as ... for". The collocation of "in" with "figure" seems strikingly strong. However, this is misleading because a detailed analysis of the corpus shows that "in" rarely precedes "figure" by itself. In order to collocate with "figure" by itself, "in" must begin the sentence, forming the phrase "In figure ..." "In figure .." occurs only four times in the corpus. "In" usually precedes "figure" only with a participle verb preceding "in" itself In other words, the token "figure" is often preceded by a phrase consisting of a past participle + "in" Table 4 summarizes the proportion of the token "figure" which is preceded by the (past participle + in) phrase.

Table 5a: Past particle phrase preceding collocates of "figure"

Word-form	No. of occurrences	Word-form	No. of occurrences
shown in	49	demonstrated in	1
indicated in	4	displayed in	1
seen in	3	calculated in	1
given in	2	used in	1
introduced in	2	presented in	1
		illustrated in	1

Table 5b: Other preceding phrases collecting with "figure"

Word-form	No. of occurrences
that in	2
noun in	11
then in	1
appears in	1

It is possible to argue why some of the tokens are used so sparingly because of semantic and functional reasons. For example, the use of "introduced" may be restricted as it may carry the connotation "shown for the first time" Nevertheless, the distinction is clearly lost to the authors as the token occurred only twice in 13 articles. Speculatively, "seen" and "given" may not have achieved wider usage because the former may be too informal and the latter too intrusive. ("Given" necessitates a giver and this may remind the reader of the author, whereas in scientific writing, the author is supposed to efface himself) Yet, the great preponderance for the phrase "shown in", as shown in table 5a, cannot be explained semantically and functionally, as "shown" has no clear superiority over other tokens like "indicated" or "presented" In most cases, these words can replace "shown" with no discernible effect to the flow or meaning of the text. Thus, semantics and function are not the deciding factors here, although if one were to split hair, "indicated" and "presented" may be more formal or refined than "shown" If the answer to the puzzle lies not in the formality or refinement of the token, then perhaps brevity is its saving grace. Scientists concerned with squeezing information into as densely a mass as possible would surely prefer a shorter word to a longer one even if it is less elegant. At this stage this can only be mere speculation It should be interesting to see whether this will be verified in later research

The lemma "figure" can also collocate with certain following words in clear patterns (see table 6). All of these words are verbs in the Simple Present Tense. Interestingly, the lemma "show" again occurs most often (63% of all occurrences). As expected, the singular form dominates (69% of all occurrences). "Figure" here is also used in an expanded sense which can be used to refer to graphs or patterns as in the following examples.

Figure 3 shows a graph
Figure 6 indicates that the central area of the pattern

The formula for integrating figures into Physics texts using following collocates seems to be

(Figure(s) n (and z) + show(s))

Nothing much can be said about the other lemmas as the solitary occurrence of each may be coincidental Their roles as following collocates of "figure" should be explored in greater depth in a future study, but the present study has established a clear trend in how the lemma "figure" is used in Physics texts.

Table 6: Words following "figure"

Words	Times occurred	% of total occurrences
shows	7	44%
show	3	19%
represents	1	6%
illustrates	1	6%
indicates	1	6%
demonstrates	1	6%
depict	1	6%
describe	1	6%

Figures can also be referred to without any linking words whatsoever. The following examples illustrate this.

The problem is simplest in the case of a plane slab (figure 1)
It is noted (see figures 2(a) and 2(b)) that
At ambient pressure, ten bands were observed in mid-IR spectrum of NH4VO3 in the DAC, figure 3.

As can be seen in the examples, the phrase [figure *n*.] can be inserted in a sentence, with or without parentheses, without any other linking words. The phrase [figure *n*.] is usually located at the end of a sentence but they can be located just as easily in the middle of a sentence, nearest to the objects they modify Sometimes, the word "see" precedes "figure" but this is quite rare. Table 7 summarizes the forms and the locations of this type of linkage. Although the trend is to use this type of linkage at the end of the sentence, it is not conclusive.

Table 7: Forms and location of ((see) figure n.)

Form	Mid-sentence	End of sentence
(Fig n)	3	
(Figs. n and z)	1	1
(see Fig. n)	–	2
(see figures n and z)	–	1
figure n	–	4
(figure n.)	8	7
(see figure n.)	–	1
(figure n (x,y))	1	1
(figures n (x, y))	–	2
Total	13	19

CONCLUSIONS

This paper shows that graphics are a significant part of Physics research articles. Graphics tend to occur in the results and method sections of these articles. In addition, graphics are integrated and linked to these research articles with very rigid structures. Thus, it would seem that it is possible to teach writing - of graphics, at least - in a fairly formulaic way

REFERENCES

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Miller, C. (1992). Rhetorical community: The cultural basis of genre. Paper presented at the Re-thinking Genre Seminar. Carleton University, Ottawa.

Swales, J.M. (1990). Genre Analysis: English in academic and research settings. Cambridge Cambridge University Press.

__________ (1992). 'Genre and Engagement' Privately circulated pre-publication paper

APPENDIX

Articles used in this study

Article code	Name of article
AP1	Xiao-Bo Wang, Ronald Pethig and thomas B Jones, *J Phys. D Appl. Phys.* 25, 905 (1992)
AP2	I. Duport, P Benech, D Khalil and R. Rimet, *J Phys. D Appl. Phys.* 25, 913 (1992)
AP3	Z. Cui, *J Phys. D Appl. Phys.* 25, 919 (1992)
AP4	R. Ducharme, P Kapadia and J Dowden, *J Phys. D Appl. Phys.* 25, 924 (1992)
CM2	M. R. Poulsen, M. Charlton, J. Chevallier, B. I. Deutch, L. V Jorgensen and G Laricchia, *J. Phys. Condens. Matter* 3, 2849 (1991)
CM3	D M. Adams, J Haines and S. Leonard, *J Phys. Condens. Matter* 3, 2859 (1991)
CM4	A. I. Morosov and A. S Sigov, *J Phys. Condens. Matter* 3, 2867 (1991)
CJP1	Y Brechet and J S. Kirkaldy, *Can. J Phys* **70**, 193 (1992)
CJP3	Khin Maung Maung, P A. Deutchman and R. L. Buvel, *Can. J Phys* **70**, 202 (1992)
EJP3	J Fujioka, *Eur J Phys.* **12**, 160 (1991)
EJP4	F Vera and I. Schmidt, *Eur J Phys.* 12, 167 (1991)
JMR3	M. J Mombourquette and J A. Weil, *J Magn. Reson.* **99**, 37 (1992)
JMR4	C S Poon and R. M. Henkelman, *J Magn. Reson.* **99**, 45 (1992)