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Enlightening
Interdisciplinarity
in STEM
for Teaching

Linguistics and STEM sciences: why is the language important for STEM scientists?

Co-funded by the
Erasmus+ Programme
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Grant Agreement n°2019-1-IT02-KA203-063184

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Summary

1) Language and its varieties
2) The variety (or register) of the scientific language
3) Textbooks: disciplines and interdisciplinarity
4) Activity
5) Conclusion

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Why? Why should I do that?

Why should we, STEM scientists, attend a class about language?

What do we care?

Well, since the work of STEM teachers is to make the students acquire scientific knowledge, and since it is mainly carried out through the language, being aware of the scientific language's characteristics and criticalities is useful and important in order to perform their task.

[...] seeing the specialist not as a pre-existing persona but someone **brought into being by the discourse itself.**

Halliday (1993: 59)

In everyday life, when we talk or write about anything, we use a code consisting of signs and relations between them: the natural language.

It is **not** the only semiotic code we use to communicate, e.g., the same way of dressing is a way to mean something, to express a message.

The natural language is, then, just one of the semiotic systems among others we use to communicate.

Anyway,

It is the **most important** and the first we acquire during life.

We used the word ***system*** to define it**:** it has a very articulated structure of elements and relations.

Signs = signifier (form) and signified (meaning)

The natural language

It works on at least four levels:

1. phonetics/graphic;
2. lexicon;
3. syntax;
4. text.

Each level presents several interconnected elements, and each level has relations with other levels.

Phonetic/graphic: e.g., *f*, *s* = /f/, /s/

Lexicon: e.g., *hou**se***, *roo**f***

Syntax: e.g., *SVO*, *syntagms*, *main clause*, *subordinate clause*, connectives (***in fact***, ***because***, ***further***, etc.)

Text: e.g., *paragraphs*, *topic VS focus*, types of text, etc.

The different elements are combined in order to form a message.

e.g., *The roo**f** of my **house** is covered with solar panels **because** I want to save energy and less expensive bills*.

The system **allows** one **to choose** how to form and express meaning, but, at the same time, it **limits** the set of possibilities to choose from.

For example, in English, we can say and write:

a) *Mary called July to invite her to Steve's birthday*.

But we can't say or write:

a.1) Mary ***to*** *called* ***invite July to*** *Steve's birthday* ***her***.

In this case, the limit regards the order of the different elements: the syntactic order.

Other limits concern morphological or lexical constructions:

e.g., in English, the plural morpheme -*s* must be put at the end of the word.

However, limits do not concern just syntactic and morphological or lexicon constrictions.

The possibilities and restrictions also vary according to the context and the situation in which we use the language.

Example 1

A: “Hi Mate, how things going?”

B: “Hi bro, pretty good. Wanna go to get a coffee?”

A: “Sure, dude! Let’s go!”

Example 2

C: “Good morning, Professor Halliday. How are the studies going?”

H: “Good morning. Professor Chomsky. Please to meet you again. We are improving our experiments. Would you like to get a coffee so that we can discuss the last results?”

C: “Of course, I do”

Example 1

- greetings and an invitation to get a coffee;
- informal situation;
- participants are friends.

Example 2

- greetings and an invitation to get a coffee;
- formal situation;
- participants are professors.

Example 1

A: "**Hi** **Mate**, **how things** going?"

B: "**Hi** **bro**, **pretty** good. **Wanna** go to get a coffee?"

A: "**Sure**, **dude**! Go!"

Example 2

C: "**Good morning,** **Professor Halliday**. **How are** the studies going?"

H: "**Good morning**, **Professor Chomsky**. *Pleased to meet you again*. We are improving our experiments. **Would you like** to get a coffee so that we can discuss the last results?"

C: "Of course, I do".

Example 1

Oral informal variety

Example 2

Oral formal variety

The scientific language

The **language of science** is **a variety (or register)** of a language.

It forms, with other varieties, the linguistic repertoire of different ways to communicate messages.

It arose after the 17th century, with the need to talk and write about new scientific discoveries **in a national language**.

Before national scientific register

Before, the language used by scientists was Latin.

First attempts

After the first attempts, an intense discussion about language started:

Galileo

Scientists needed a language that represented and communicated the new ways to look at the world and described its laws.

A new way to look at nature -> new methods of researching, **new language**.

It **wasn't** just **translating** from Latin to a national language.

It was an operation of "reforming" science through language, **a reforming of the scientific discourse.**

Characteristics of the scientific language

It differs from other varieties/registers for at least **three features**:

1) It is spoken and written **by a specific community**, that is, the **scientific community**;
2) it has a **specific vocabulary** (technical terms);
3) it is characterized **by a preference for some syntactic constructions** among all those that are possible in the system.

At the very beginning, the main processes aimed to form a language for science concerned:

- **lexicon** (finding words able to convey a specific and technical concept);
- **syntax**.

Lexicon:

pointer, *golden ratio, dark energy, the pythagorean theorem*

general concept (*motion*);

specific concept (*rotational motion*)

apparatus (*micrometer*);

methodology (*mental experiment*)

Lexicon/syntax

In scientific prose, the necessity to define and describe properties and relations between entities/phenomena carries the use of the verb *to be* as ***a copula***, connecting syntagms (nouns, adjectives, clauses):

Mass is *the quantity of matter in a physical body.* ***It is*** *also a measure of the body's inertia [...] (From Wikipedia)*

But there are, of course, other verbs types:

- ***thinking and reasoning*** verbs, like *to suppose*, *to hypothesize*, *to image, to observe,* etc.;
- verbs explaining **"procedure"**, like *to calculate*, *to obtain*, and so on.

Syntax

Aside from the **vocabulary** (most of it was formed by taking words from ancient Latin and Greek languages, es. *kinesis* from Greek *kìnesis* ‘movement’), a significant change in the use of language concerned a syntactic choice: the phenomenon of **nominalization**.

The nominalization consists of making an adjective, a verb, or an entire clause become **a noun**.

For example:

refracted > reflection

In this way, a process or a quality becomes a **defined entity**. Consequently, its existence is presupposed and can be taken as a starting point for a new message, a topic to which to add information.

It is an *objectification*.

For the same reason of *objectification*, in the scientific language, the use **of passive and impersonal verbal forms** is preferred: the scientist acquires the role of observer of entities.

Examples:

The element **has been discovered** [...]

It seems that [...]

Implicit **subordination** (formed by gerundive or participle verb and without expressed connectives, e.g. *in fact*, *since*, *because*, etc.) is another syntactic feature. This leads to make the logical relation among senteces implicit.

Examples:

- *Knowing that > since / because we know that*
- *Given that > since / because we give X for granted*

However, **the coordination and juxtaposition** prevail (especially in the last four decades) on the subordination.

Text

On a textual level, the scientific language often use other semiotic codes:

- logical symbols;
- charts;
- tables;
- figures;

The text is characterized by **lexical density**, which means the extensive use of nouns related to each other and fewer grammatical words: this leads to a density of content.

To sum up

It is a **complex system** of technical terms, syntactic choices, and the structure of the text.

The changes

This variety's studies started around the 1960s in Great Britain (for the English language).

However, the variety **is not stable and homogeneous** for every kind of text (and situation) or discipline.
It **evolves** through **time**, **space**, **channels**, **and communication aims**.

Time: the scientific language nowadays differs from the scientific language of Galileo, as it differs from the scientific language of fifty years ago.

Galileo used words, syntactic choices, and the type of text as dialogue which are not available today.

Even looking fifty years ago: syntax changed. Nowadays, coordination is much more preferred than subordination.

Space: of course, the scientific English differs from scientific Italian, from scientific Spanish, etc.

Space: in Italian, the pronouns as ***I*** and ***we*** are rarely used in scientific texts (even if the influence and the prestige of English is affecting the Italian usage);

Fields: the scientific language of one discipline differs from another.

Field: every discipline has its own vocabulary, even if it is possible sharing terms. For example, the word *valency* means two different concepts in two different fields; in linguistics, it concerns the constructions of verbs; in chemistry, it concerns the propriety of an element.

Field: lexicon

The lexicon is the level on which this differentiation is most evident.

Physics: *movement, force, mass, projectile*, etc.

Mathematics: *equation, formula, binomial, coefficient*, etc.

Computer science: *abstract data type (ADT), ASCII, prolog*

Field: syntax

Another difference is about syntax:

some constructions are more frequent in specific texts than others, as the followings:

Mathematics:

- *If x than y*
- *For all…we have…*

Field: text

Another difference concerns the textual level: we already saw that **different codes** are used in the text to give information.

Disciplines can differ in the type of codes and annotation used.

Channels: written or oral. In the oral variety, the language is simplified in structures, especially syntactic ones.

Situation:

participants can be:

- all scientists;
- lecturer - students;
- lecturer - common people.

Situation

Participants can be:

- all scientists -> aim: sharing and discussing theories, hypothesis, results; ***argumentative and informative texts***;
- lecturer - students -> aim: informing; ***informative texts***;
- lecturer - common people -> aim: disseminating; ***informative texts***.

The situation and the aims lead to adjust the language to the addressee of the message, considering:

- his/her knowledge of the subject;
- his/her knowledge of the register;
- their expectations.

So, the language and texts addressed to scientists differ from those addressed to students and aimed to dissemination.

Let's see some examples:

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Scientific paper:

Characteristic vectors of bordered matrices with infinite dimensions, by Wigner, 1955

- technical terms;
- nominalization;
- passive verbal forms;
- different codes

BY EUGENE P. WIGNER

(Received April 18, 1955)

Introduction

The statistical properties of the characteristic values of a matrix the elements of which show a normal (Gaussian) distribution are well known (cf. [6] Chapter XI) and have been derived, rather recently, in a particularly elegant fashion.[1] The present problem arose from the consideration of the properties of the wave functions of quantum mechanical systems which are assumed to be so complicated that statistical considerations can be applied to them. Since the physical problem has been given rather recently in some detail in another journal [3], it will not be reviewed here. Actually, the model which underlies the present calculations shows only a limited similarity to the model which is believed to be correct. Nevertheless, the calculation which follows may have some independent interest; it certainly provided the encouragement for a detailed investigation of the model which may reproduce some features of the actual behavior of atomic nuclei.

All the remaining work will deal with real symmetric matrices of very high dimensionality. The first and last problems concern infinite bordered matrices; the second one a finite matrix the consideration of which served as an intermediate step toward the solution of the last one. We mean by a bordered matrix the sum of a diagonal matrix **k** and a border matrix **v**. The diagonal elements of **k** are all the integers $\cdots, -2, -1, 0, 1, 2, \cdots$. The border matrix **v** has non vanishing elements only up to a distance N from the diagonal, the absolute value of all the non vanishing elements is the same

$$(1)\qquad \begin{aligned} |v_{mn}| &= v && \text{for } |m-n| \leqq N, (-\infty < m, n < \infty) \\ &= 0 && \text{for } |m-n| > N. \end{aligned}$$

Since the matrix $H = \mathbf{k} + \mathbf{v}$ is symmetric, $v_{mn} = v_{nm}$. Subject to this condition, however, the signs of the v_{ij} are random, i.e. we consider ensembles of matrices with all possible signs of v_{mn} subject to the conditions of symmetry. In the first of the problems considered $N = 1$, in the third one both N and v are very large in such a way, however, that $v^2/N = q$ remains limited. The first problem will be solved completely, i.e. the characteristic values and vectors given explicitly.

Linguistics and STEM education: why the language is important

1

Simple models of the atom

1-1 INTRODUCTION

We know that classical physics, as represented by Newtonian mechanics and Maxwell's laws of electromagnetism, works marvelously well for the analysis of the behavior of macroscopic objects in terms of empirically determined laws of force. But as soon as we enter the world of the atom, we find that new phenomena appear, requiring new concepts for their analysis and description. The whole realm of phenomena at the atomic or subatomic level is the special province of quantum theory. However, because the behavior of matter in bulk ultimately results from the properties of its constituent atoms, our deeper insights into physical phenomena on the macroscopic scale will often also depend on quantum theory. For example: We can do a vast amount of useful analysis of the mechanical behavior of solids using measured values of their elastic constants, tensile strengths, etc. But if we want to account for these measured values in terms of more fundamental processes, we must invoke quantum theory. It is at the root of our whole understanding of the structure of matter.

The properties of atoms—and even the fact of their existence—pose a series of questions unanswerable by classical physics:

> Atoms are typically a few angstroms in diameter (1Å = 10^{-8} cm) with remarkably little difference in size between the lightest and the heaviest (see Figure 1-1).

1

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Textbook:

An introduction to Quantum Physics, by French & Taylor, 1978

- usage of *we*;
- definitions;
- discourse is a progression in acquiring knowledge;
- usage of ambiguous lexicon (*marvelously*).

software, instructions that tell a computer what to do. Software comprises the entire set of programs, procedures, and routines associated with the operation of a computer system. The term was coined to differentiate these instructions from hardware—*i.e.*, the physical components of a computer system. A set of instructions that directs a computer's hardw to perform a task is called a program, or software program.

Key People: Steve Jobs • Bill Gates • Larry Ellison • Ray Kurzweil • Azim Premji

Related Topics: open source • malware • Adobe Flash • ICQ • plug-

See all related content →

The two main types of software are system software and application software. System software controls a computer's internal functioning, chiefly through an operating system, and also controls such peripherals as monitors, printers, and storage devices. Application software, by contrast, directs the computer to execute commands given by the user and may be

dif·fer·en·ti·ate

\ ˌdi-fə-ˈren(t)-shē-ˌāt \

verb

: to obtain the mathematical derivative of

: to mark or show a difference in : constitute a contrasting element that distinguishes

: to develop differential or distinguishing characteristics in

Webpage:

from *Encyclopedia Britannica*
-definitions;
-links for definitions;
-history of the term;
-use of impersonal forms.

Texts are **adapted** to the aims and the addresses.

Sometimes, the information is **implicit**.

This is because that information **is given for granted** or considered **easily reconstructable** by the addressee.

In the third case, we find **definitions**: the writers know that the readers lack the knowledge needed to understand the text. Thus, the words must be defined **to form the concepts** they convey in the addressee's mind.

In linguistics, we differentiate the implicit information as

- **presuppositions**: when the content is given for granted;
- **implicatures**: given some information, the addressee can reconstruct the implicit content (adding content).

a) *Try again* = you *already* have tried before;
b) *Given that* x > y = *we give* for sure that x > y
c) *Probably the results will change* = they could not change.

Indeed, recognizing implicit information by the addressee depends on two main factors: 1) on the knowledge of the addresses; 2) on the ways in which the information is conveyed (on the structure of the text).

So, all unknowns by the addressee should be expressed in a textbook.

Attention!

Not everything has to be expressed: just the information needed to understand the message for a non-expert.

To sum up:

the linguistic choices made for describing discipline content suggest the representation of the discipline itself to the addressee.

Considering the teaching environment and **textbooks, this is crucial when the addressee is a student**.

Textbooks

Informative /expositive function

Textbooks are addressed to students who have to construct their knowledge of a specific discipline.

How the textbook (or the professor) conveys and represents the discipline is very important in understanding the discipline itself: its theories, methods, and results.

The students must acquire the scientific register to think, talk, write scientific content and communicate (even without being part of it) with the scientific community.

They have the following characteristics:

1) nominalization;
2) coordination prevails above subordination (that is often implicit);
3) the text is divided into paragraphs for each concept: one paragraph - one concept;
4) It uses keywords and summaries to facilitate the acquisition of the main concepts;

4) different codes: repetition of the same content but in different codes (*redundant*);

5) (should have) definitions and explanations of technical terms, methods, etc.;

6) usually, pronouns like *you or we* are preferred, trying to involve students and the metaphor of the journey (like the TV documentaries);

7) science is treated as a mystery and magical (ambiguous lexicon, exaggeration, from TV documentaries).

Lexicon

Usually, the problematic comprehension of an (oral or written) scientific text is commonly associated with the difficulty of technical terms because they convey concepts not known by common people: *Doppler's effect*, *mass*, *cipher*.

Textbooks (should) present definitions of such terms.

This practice should be meticulous, especially with ambiguous terms: *mass*, *cipher*. The first can be used in a common language to refer to an extensive group of people; the second is shared between Physics and Mathematics but with two different meanings.

Lexicon: verbs and nouns describing science

Considering verbs and nouns, the reader will acquire an image of what the discipline is, what it does, and how it relates to other fields according to the meaning of verbs and the nouns used in the textbook.

For example, using just verbs of *procedure* will give the reader the image of a discipline as a list of operations to do: it will be focused on the *operational part*.

And the same happens if the authors prefer to use nouns related to the same semantic field of ‘operation’= *work*, *technique*, etc.

Lexicon: verbs and nouns describing science

At the same time, if the lexicon is correlated to concepts referring to reasoning processes (*idea*, *conception*, *theory*, *supposition*, *observation*, etc.), the image will be focused on the reasoning and theoretical part of the science.

Syntax

The **preference** for subordination without connectives or for coordination and juxtaposition leads **to making the logical relations between the clauses** (e. g., cause-effect, finality, consequences) **implicit**.

e.g., I am sad. I am going home.

Being sad, I am going home.

It is not explicit that the sadness is the cause of the decision to go home, which is its consequence.

We reconstruct the relationship between the clauses:

***Because** I am sad, I am going home.*

or (in the first case)

*I am sad, **so that** I am going home.*

Syntax

Using sentences with these implicit constructions can create a deep gap between students who can reconstruct the implicit content and those who cannot do it.

An explicit subordination, instead, with connectives, such as *because*, *in order to,* allows to make these relations explicit. The expression of the logical connections between clauses and their information should make the reasoning clearer to the student.

Syntax

The same nominalization can be a problem.

The nominalization gives the status of *entities* to process and properties and, consequently, it takes them *for granted*, but this makes the reading more complicated because it hides the features of the observed phenomenon.

So,

If these same constructions in texts addressed to the scientists' community are justified and possible by the fact that scientists can understand the relations between contents by being aware of the scientific methods and experimentation, the same syntactic constructions in textbooks are a risk of misunderstanding.

Coordination and juxtaposition are considered mechanisms of simplification,

but

simplification is not always the answer to solving the problem of comprehending complex concepts.

Scientific reasoning is complicated, so too much-simplified language **cannot convey the complexity**.

Simplification should not be interpreted as a reduction of the notion but **as unpacking of information**.

Textual structure

Moreover, the textual structure can imply interdisciplinarity but not makes it clear, giving it for granted.

Sometimes, textbooks seem to be a list of procedures, like

"First, we do this…"

"Then…"

The temporal connectives suggest a representation just as a list of *things to do*, reproducing the same image of *procedural* verbs and nouns.

What about interdisciplinarity?

Scholars have noted that most parts of the textbooks do not focus on interdisciplinarity, or it is very simplified.

The interdisciplinarity representation can be detected by looking at the lexicon (nouns and verbs) used and how the syntax and textual structure relate to the contents from different disciplines.

The professor has to be aware of all these problems and eventualities.

Look at some textbooks to analyze the representation of one discipline and interdisciplinarity.

Activity: analysis of textbooks

- 20’ minutes to read the text;
- 30’ minutes to analyze it.

Activity

Physics

Walker

Computer science

Bonhen&Shoup

For simplifying the analysis, we use a grid.

It considers a textual, syntactical and lexicon levels:

Textual level

1) Which semiotic codes, in addition to the natural language, are used in the texts, and which functions do they have in conveying information (e.g., adding information, explaining data, etc.)?

2) How are the texts structured (how many paragraphs, what are their contents)? How do their structure and information progression affect comprehension?

3) Do you find any implicit information (something just intended by the author but not directly expressed)? If yes, what is and where is it?

Syntactic level

4) What type of clauses are present in the text, and what does prevail? Subordination or coordination? Moreover, what information do the subordinate and coordinate clauses express (e.g., cause and effect relationship, temporal relationship, contrasts, consequences, conditions, etc.)?

Lexical level

5) Which are the most frequent verbs and nouns concerning what science does in the text? What do they mean (e.g., verbs of action or thinking, other meanings)?

Lexical level

6) Which words are technical/scientific terms? Do they concern the general concepts of a discipline, its specific concepts, methodology or apparatus (instrument), process, or attributes?

7) Do you find technical terms shared by disciplines? Try to identify the technical terms and what discipline they belong to: do you think some terms or lexicon constructions can be part of more than one discipline vocabulary?

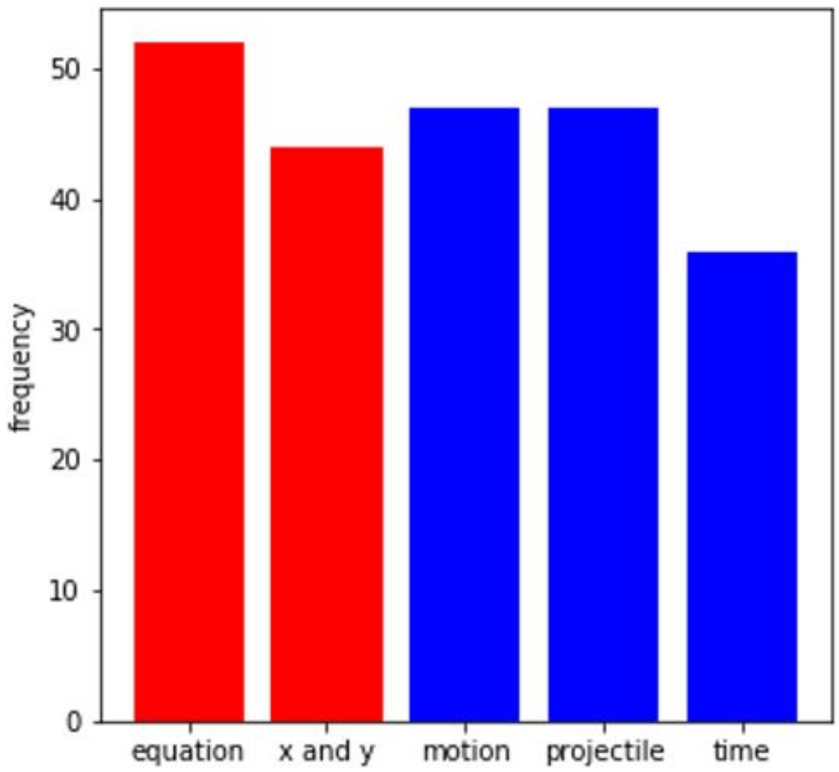
General level

8) Do you think the textbook is understandable for a non-expert reader?

9) How do the texts describe disciplines and interdisciplinarity? What do they, and how do disciplines interact?

Discussion

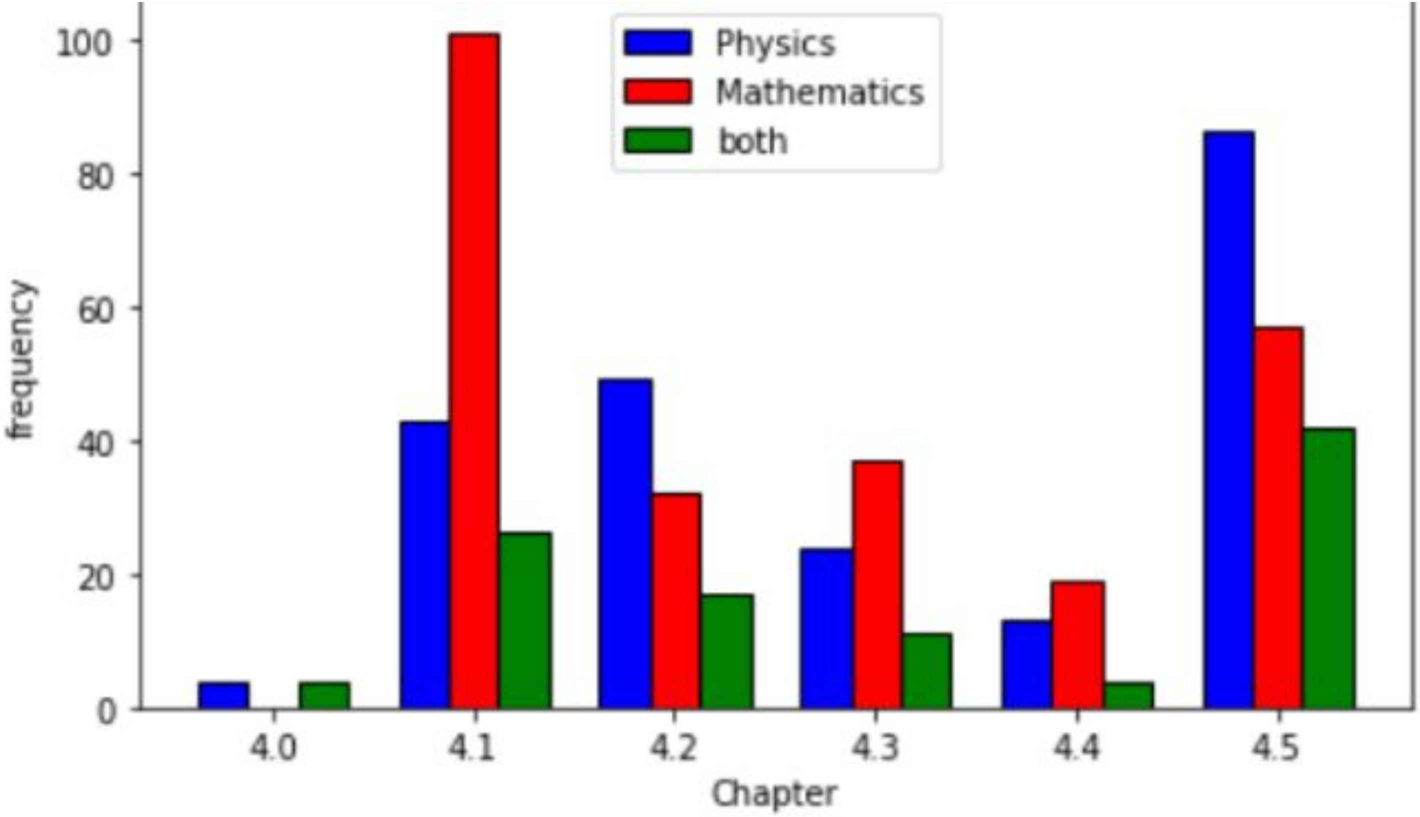
Nouns



·the·

5·most·frequent·technical·terms·in·the·chapter¶

Nouns


Physics
Mathematics
both
100
80
60
40
20
0
frequency
4.0
4.1
4.2
4.3
4.4
4.5
Chapter

Verbs

The result: aside from copular verbs, we found that most verbs are related to the procedure (*procedural verbs*), which means they represent physics as a collection of operations, and most of these operations are mathematical calculus.

To <u>obtain</u> *y as a function of time,* ***we <u>write</u>*** *y in place of x […]*

<u>Substituting</u> *these specific values into our fundamental equations for projectile motion (Equations 4-6) gives the following simplified results […]*

Verbs

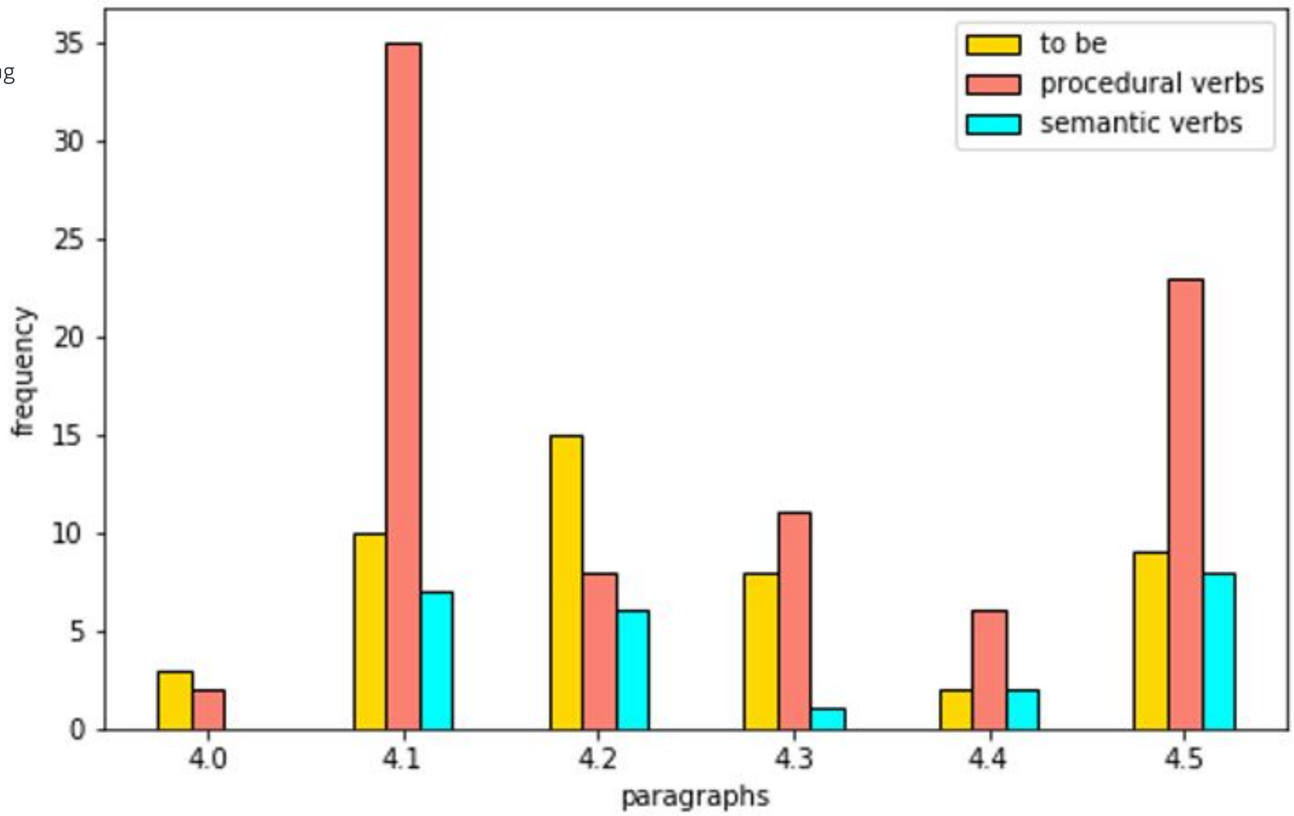
Anyway, we can also find verbs relating to the semantic field *of reasoning*, like "to consider", "to notice", "to suppose", etc.:

Notice *that the ball goes straight down, lands near your feet, and returns almost to the level of your hand in about a second*. (page 93)

[…] *then* ***observe*** *its motion carefully.* (page 93)

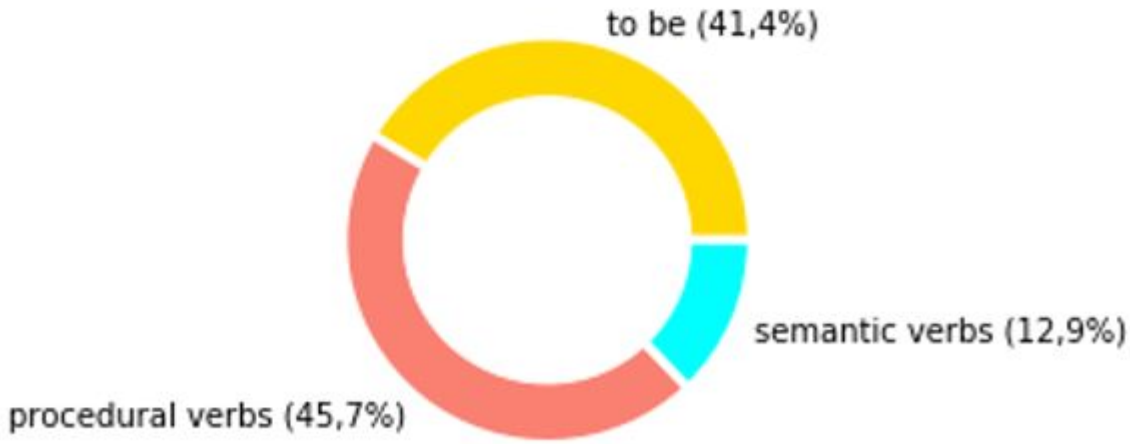
From Equation 4-12 we ***see*** *that R varies with angle as sin 2θ*. (page 104)

Verbs



Trend·in·verbs·frequency·within·the·chapter¶

Verbs



of·verbs·into·the·three·identified·types¶

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