

**VERB TYPES IN CHEMISTRY RESEARCH ARTICLES:
A SEMANTIC PERSPECTIVE**
**Tipos de Verbos em Artigos de Pesquisa na Área de Química:
uma Perspectiva Semântica**

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Abstract

Semantic verb types in chemistry research articles and their collocational structures have been analysed in order to determine the most highly co-occurring verbal patterns in a specific genre. In order to carry out this study, a selection of 25 articles from specialised journals has been processed with a concordance programme. Pedagogical implications regarding sense choice and the syntactical patterns they select in order to convey a specific sense are discussed in the paper. This paper analyses only the use of the thirty most frequent lexical verbs found in our corpus and is limited to the use of those verbs in the contexts where they have been found.

Key-words: *corpus analysis; ESP; language teaching; materials design.*

Resumo

Este estudo analisou tipos semânticos de verbos em artigos de pesquisa na área de química e suas estruturas colocacionais, com o objetivo de determinar os padrões verbais que co-ocorrem com mais frequência em um gênero específico. Para realizar este estudo, 25 artigos de periódicos especializados foram processados por um programa de concordância. Implicações pedagógicas relacionadas a escolha de sentido e os padrões sintáticos que selecionam para transmitir um determinado sentido são discutidos neste artigo. O artigo analisa apenas o uso dos 30 verbos lexicais mais frequentes encontrados no nosso corpus e limita-se ao uso desses verbos nos contextos em que foram encontrados.

Palavras-chave: *análise de corpus; Inglês Instrumental; ensino de línguas; elaboração de materiais.*



1. Introduction

The present study is concerned with the use of the 30 most frequent verbs appearing in articles dealing with technical ceramics. The creative power of verb collocational patterns and their implications in the production of ESP classroom activities is one of our main concerns. We believe that, as Jacobs (1991:35) has pointed out when he discusses knowledge sources for sense discrimination, “topic (...), the general context in which a word is used, is as important as the specific way it is used”. Studies like the ones carried out by Sinclair (1991), Biber, Conrad and Reppen (1994), Conrad (1999) or Cowie (1981), among many others, demonstrate how corpus analysis and collocational patterns provide useful information on particular aspects of language use. When a significant number of collocates of a word share one or more semantic features, it is possible to elaborate a sketch of the semantic behaviour and syntactic patterns that illustrate the meanings and use of a node or selected word.

2. Method

In this paper we have selected 25 research articles dealing with the topic of technical ceramics. Although it is a very small corpus, the subject has also been narrowed down to a specific research interest for Chemistry students in our university: technical ceramics. The results of this study therefore analyse a well-delimited area of research, an issue which is even more relevant due to the fact that most students will possibly work for ceramic companies in the future. A corpus was elaborated with articles belonging to the following research journals: *American Ceramic Society Bulletin*; *Interceram*. *International Ceramic Review*; *Journal of the American Ceramic Society*. The articles selected were published between 1996 and 1997. All articles were processed with a concordance programme (WordSmith Tools 2.0) and results from this analysis are organised and used to create theoretical information for classroom use and activities responding to the behaviour of words within this particular topic. The language scope covered here ranges from 1996 to 1997.



3. Results

The following 30 verbs were the most frequent in our corpus. Each verb was analysed in the context it appears so that collocational information could be retrieved. The verbs are grouped in four sections regarding semantic similarities or their use in a similar situation. Thus, group A contains verbs related to a mental process; group B includes verbs expressing some kind of comparison; group C lists verbs used to express that an event or a state is brought about; and finally verbs in group D refer to the manipulation of something. The information contained in this section may be used as theoretical information for the classroom. For each group, relevant collocates of the verbs are also discussed. The collocates considered here include both nouns and prepositions. Occasionally, adverbs and verbs also collocate significantly with the verbs analysed here (verbs appear as collocates to form verbal periphrases).

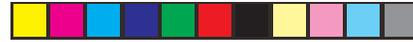
GROUP A) A number of the most frequent verbs refer to a mental process where the researcher finds out something about a method, material or process. These are the verbs *calculate*, *consider*, *determine*, *show*. *Observe* and *study* refer to the previous action that leads to the finding.

CALCULATE: The most frequent collocates of *calculate* are *coefficients* with the preposition *from* or *with* (can be calculated from / something is calculated with absorption and scattering coefficients), *values*, *parameters*, and the word (*observed*, *non-corrected*) *transmittance*:

- (1) The absorption and scattering coefficients of turbid media could be **calculated** from observed transmittance

The words *via/with/using* introduce the way or method used in the calculation:

- (2) difference was **calculated** using an equation which ...
- (3) damage resistance parameter R_t was **calculated** via equation



CONSIDER: collocates with the words *method, results, model, details*.

- (4) kinetic model may be **considered** for these heterogeneous
- (5) results were **considered** sufficient in order to

The expression “was/were considered to be + participle/adjective” is preferred instead of a direct statement of the type “It/this was caused/influenced by ...” and expresses a more impersonal point of view or a lower degree of conviction:

- (6) with clay content was **considered** to be caused mainly by iron
- (7) these coefficients are **considered** to be influenced by size, distribution, ...
- (8) was therefore **considered** to be negligible.

DETERMINE: The infinitive (expressing an end or finality) appears in periphrases of the type “calculated to determine”, “conducted to determine”, “used to determine”, etc. where a specific activity leads to a determination, or preceded by adjectives like “difficult to determine”, “necessary to determine”.

Words related to some kind of measure, like *value, parameters* or with the characteristics of some material, like *fracture, mass, viscosity, size* are the most frequent collocates of *determine*. The preposition *by* introduces a method:

- (9) was then conducted to **determine** the effect of viscosity on
- (10) it is often difficult to **determine** the exact values of the
- (11) the parameters that **determine** the molecular size and
- (12) phase chemistry were **determined** by X-ray fluorescence

OBSERVE: The most frequent collocates of *observe* are those related to the form or some negative result in the materials: *crystals, (micro)structures, grains, differences, impurities*. Words such as *values* and *phases* are also usual collocates:

- (13) mullite crystals were **observed** by SEM. Such
- (14) higher than the value **observed** for the crystalline phase



SHOW: *Show* differs from the previous verbs in that here the researcher somehow assists the reader to perceive something. Thus, words like *behaviour*, *tendency*, *trend*, *performance* collocate with *show* to indicate how something develops and what happens when a specific material or method is employed in an experiment:

- (15) with wavelength **showed** almost the same tendency as
- (16) All binders **showed** the same performance

Show is followed by a long *that*-clause to introduce a hypothesis that has been demonstrated:

- (17) the diagrams for the measurement of roughness **show** that after a rather rough grinding (used for roughing but not for overfinishing), the ceramic components have a high degree of settling, although they were obtained in ordinary conditions of compressing and sintering.

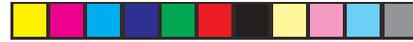
This verb collocates with *figure(s)*, *data*, *tables*, etc. usually introduced by the preposition *in* and also appears with percentages:

- (18) Figs. 9-13 **show** the microstructure of the
- (19) mullite gels **show** up to 35 % linear shrinkage and

STUDY: Objects collocating with *study* are words referring to the characteristics of the materials under examination or their reactions when applying certain techniques or carrying out experiments with them: *gravity*, *properties*, *thickness*, *characteristics*, *behaviour*, etc. Collocates for this verb also include words indicating contrast or comparison such as *relationship*, *the influence of*. The structure “X was/were used to study Y” is also frequent, and thus a method or a particular equipment (*viscometer*, *tests*, *thermogravimetric analysis*) may be used to study something:

- (20) specific gravity was **studied**. A controlled viscosity was

TEST: The verb *test* collocates with *samples*, *systems*, *rate(s)*, *viscosity* and is also found in the prepositional structure *was tested against* (which is a combination used in a domain-specific sense: contrast with, and so things are tested against a pattern or a model, or hypotheses are tested against previous experience or experiments):



- (21) Then, a combination of samples A and B were **tested** against a combination of samples B and C.
- (22) samples were **tested** in accordance with the two
- (23) desired viscosity was **tested**. The results suggest that

GROUP B) Some verbs refer to differences or similarities. The verb *measure* expresses how the researcher tries to find out differences or similarities between two things or processes. *Improve* expresses how something is done to correct or make the differences more suitable. *Compare* (*parameters, resistance, temperature, different materials, etc.*), and *develop* would also belong to this type though they are less frequent.

MEASURE: The majority of the objects of *measure* allude to qualities and properties: *toughness, absorption, thickness, shock resistance, transmittance* and also to quantity: *rates, time intervals, etc.:*

- (24) thicknesses were **measured** and some of them were
- (25) time intervals is **measured** as a squareroot function of

When the method of measurement is indicated, it is introduced by the words *by/with/using* or by *on* when it is an apparatus; adverbs or adverbials introduced by the preposition *at* are used to express how something is measured:

- (26) and prepared bodies **measured** by X-ray fluorescence
- (27) constant was **measured** on a Hewlett Packard 419A
- (28) damage thresholds **measured** at more than 9 J/cm² at
- (29) samples are being **measured** simultaneously, it is not

IMPROVE: *Improve* collocates with words which are all understood as desirable conditions or ends: *efficiency, quality, performance, properties, design, characteristics, behaviour, etc.*, that is, good performance, better casting rate, the best quality, and so on, even if the “good, better, best” is implicit in the sentence:

- (30) requirement, but to **improve** efficiency of the systems
- (31) should be used to **improve** plant performance. The
- (32) fewer fines should **improve** the casting rate;



GROUP C) Another group refers to how the researcher or the characteristics of the material under examination do something to bring about an event or state, to make it possible: *make, achieve, allow, permit, cause, lead to*.

ALLOW and PERMIT: It is interesting to note the use of both *allow* and *permit*. *Allow* but not *permit* may be used in the passive voice followed by an infinitive. With the infinitive it implies that no external action affects the materials during the process:

- (33) and the parts were **allowed** to cool for 30 s prior to
(34) The feedstock was **allowed** to mix until the torque

Both *allow* and *permit* are frequently used to express that things or experiments are carried out without any difficulty. The agent that collocates with *permit* or *allow* in this sense is usually formed by words or phrases like *analysis, comparison of..., collection of (much) data, measurements*:

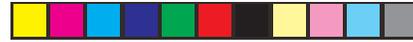
- (35) These data **allow** the absorption and saturation ...
(36) the better definition of the new method **permits** a better fit for the absorption and

the object may be words like *characterization, control, study* or words referring to positive results like *successful processing, optimization of process*:

- (37) (a supply in) the contact container **permits** control of the water level

ACHIEVE: Collocates with objects (or subjects when the passive voice is selected) that denote a positive degree or quality: *full density, high precision/quality, uniformity, the desired powder-loading, success, improvement*, and also with words like *rate, parameters, (viscosity) target, phase*:

- (38) powder was added to **achieve** the desired powder-loading
(39) full density was **achieved** in all cases. The high levels
(40) saturation phase was **achieved** at 3.1 min, and, in this



CAUSE: Usually collocates with negative words (*substantial/greater proportional loss, multiple errors, worsening, damage, unreliable measurement, contamination, defective drying*):

- (41) of the processes that **cause** porous building material degradation
(42) Both differences probably were **caused** by a greater proportional loss of water

LEAD TO: is followed by nouns which are modified by adjectives indicating some kind of degree or mode: *decreased, reduced, faster, high(er), significant, large, catastrophic, continuous, spontaneous*. The nouns these adjectives modify usually refer to some kind of change in a material or a process: *formation, cracks, transformation, breaking, increase, etc.*:

- (43) size which ultimately **lead** to cracks on the surface or in
(44) tools. This ultimately **leads** to a significant increase in the
(45) characteristics which **lead** to a decreased performance are

PREPARE: *Prepare* collocates with the prepositions *from, with, at, through* and with nouns like *slip, slurry, etc.*

- (46) Suspensions were **prepared** at 50% solid added pieces of
(47) Composites can also be **prepared** from mullite ZrO₂ glass
(48) of the slurries **prepared** under industrial conditions
(49) Slips were **prepared** using specific formulas and

PRODUCE: *Produce* is used to express the result of a process as an end or as an improvement or change in comparison to the previous state: *a significant increase, satisfactory slips, an important quantity, coarser particles, sanitaryware, etc.* The preposition *by* introduces a method or process:

- (50) was too porous to **produce** satisfactory slips for actual
(51) reaction sintering **produces** coarser ZrO₂ particles than
(52) Powder A is **produced** by the carbothermal reduction process

MAKE: has a causative sense in examples where the object is followed by an adjective (frequently followed by another verb in the to-infinitive form):



(53) These attributes **make** AIN an attractive material for

(54) of these parameters **makes** it possible to relate them

GROUP D) A different sense of *make* is to express that an agent manipulates something so that it is changed to some extent. Verbs belonging to this semantic type are: *make, heat, cool, quench, sinter, cast, dry, increase, decrease, reduce, mix, cut, mill*, etc. Only the most frequent are discussed here.

With the preposition *of* (indicating composition) or *from* (indicating source), *make* has the sense of producing by putting materials together, manufacture:

(55) components were **made** from this recycled feedstock

(56) The component is **made** of aluminous ceramics

Make collocates with *comparison, test, components, observations, test samples*, etc. and in the same sense (though not as frequent as *make*) we find the verb *perform* collocating with *tests, studies, method*:

(57) Comparison was **made** between the new and standard

(58) types of tests were **made**: Comparison between the new

(59) The tests were **performed** in an Instron machine with

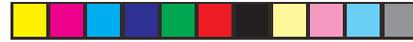
USE: For *use*, something is manipulated to change or develop something else. Words like *method, tests, system* and words denoting different *materials* are the usual collocates functioning as the subject of *use*:

(60) The same method was **used** for the analysis of the

The gerund, *using*, frequently introduces a method, a machine, or an equation:

(61) were measured **using** the Hitachi Colour Analyzer

Used is followed by *to* introducing a specific activity (*compare, determine, describe, form, obtain, represent, study*). It is followed by *for* to indicate a purpose and is followed by a gerund or a noun and the preposition *of*:



- (62) the Biot number is **used** to represent the heat transfer
- (63) transducer was **used** to compare the energies applied
- (64) the water can be **used** to control chemical and physical
- (65) method was **used** for calculating the fractional
- (66) casting is also **used** for the production of wash

The prepositional phrases *in comparison*, *in (the) production (of)*, *in X calculations*, *in this paper/study* collocate with *use* and follow it:

- (67) This is especially **used** in production of WC models. The
- (68) strength was **used** in R calculations. The present

CAST: The verb *cast* collocates with *bench casting*, *shank casting* and different types of *pressure*, and with the words *model(s)*, *slip(s)* functioning as an object:

- (69) models cannot be **cast** at pressures higher than 10 bar
- (70) if it has already been **cast** by bench or shanks casting
- (71) casting can be **cast** by high-pressure casting with
- (72) it is now possible to **cast** 8 different wash basin models

These collocations are also frequent in the nominalisation of the verb: *cast/casting processes* together with the collocations *drain-cast*, *solid-cast*, *hollow cast* (“Medium-pressure casting is also used for the ...”; “Shanks or battery casting is used in the production of ...”). When it is possible to use a verb to denote a process it is not usually employed in a verbal form and the preference is to use the nominalised form. Such is the case of *casting*, *cooling*, *cutting*, *drying*, *heating*, *milling*, *mixing*, *packing*, *debinding*, *pressing*, *processing*, *scattering*, *sintering*. Only those verbs where the verbal form is frequent are commented upon in this paper. Deverbal nouns indicating a process usually collocate with the prepositions *before*, *during*, *in*, *after*, *by*, and with the nouns *phase*, *time*, *rate*, *speed (of)*, *cycles*, *steps*; *moulds*, *models*, *slips*, *samples*, and words that refer to the success of the process or lack of it (*excessive*, *erroneous*, *successful*, *correct*, *incorrect*, etc.).

DRY: collocates with *sample*, *slip*, *moulds* usually in the passive voice:

- (73) The mixed slip was **dried** and shaped into discs (44 mm).



The noun *drying* indicating a process frequently co-occurs with negative collocates like: *defective, excessive, no, erroneous*. The noun most frequent collocations are: *spray-drying step/phases; spray-dried (powders)*.

HEAT: collocates with the preposition *in* to introduce the place where the heating process is carried out:

(74) on all sides, were **heated** in a vertical tubular furnace

The prepositions *to* and *at* introduce temperature and time: AT + °C/min + TO + °C:

(75) Y203 samples were **heated** at 2.5°C/min to 1835°C.

The noun appears in the collocations: *rapid heating, infrared heating, heating rates, cooling or heating* and prepositions like *during*.

MIX: The most frequent collocates of *mix* are: *constituents, feedstock, slip, powder*. The syntactic structure “mixed at (a solids loading of x vol % / 180rpm) at 120 °C” appears frequently in the co-text of *mix*:

(76) constituents are not **mixed** and stirred well, then the size

(77) The feedstock was **mixed** at 180 rpm at 120°C. Initially

DECREASE and REDUCE: In the present tense, *decrease* and *reduce* show preference for the use of different syntactic patterns. For *decrease* the thing that diminishes is the subject, for *reduce* it is the object: X decreases / Y reduces X.

(78) Green bulk density **decreases** as the chain length and

(79) ware and, thus, **reduce** the number of rejects. For

The most frequent collocates for *decrease* and *reduce* are words related to the quality of the materials or process: *performance, density, gravity, (impurity) levels, contamination, wear*:

(80) impurity levels can be **decreased**, which should lead to

INCREASE: Words preceding the verb *increase* are related to quantity or strength, weight, volume or value: *concentration, pressure, mass,*



density, size, value, number. The words following *increase* usually refer to some kind of process: *production, powder loading, conductivity, reexpansion*. Adverbs indicating degree may also follow the verb *increase* (e.g. *significantly*). When the starting and final point of the increase are quantified, prepositions (*from – to*), and the expression *up to* are used:

- (81) grain size also **increases** from 3.11 to 3.25
- (82) have continued to **increase** the thermal conductivity of
- (83) with PVA binders **increase** significantly as

GROUP E) In a give and take process information is obtained or provided while problems are presented or “present themselves”.

OBTAIN: Collocates with words related to numerical information: *results, data, coefficients, equations, information, etc.* and words related to some material quality: *density, absorption, etc.*

- (84) data can easily be **obtained** experimentally

Prepositional syntactic structures with *by* (indicating method) and *from* (indicating source) can be seen in examples like:

- (85) The equations are **obtained** from simplification of the
- (86) effects can be **obtained** by sintering at different

PRESENT: This verb collocates with: *problems, difficulties, a few cases, cracks, etc.* When used with the preposition *in*, it introduces figures, *at* is selected for meetings:

- (87) (over 1.5 mm), even **presenting** cracks. In Table 2, the
- (88) from alkoxide often **presents** problems due to the
- (89) is based on a paper **presented** at the American Ceramic Society Convention
- (90) is 0.994. The results **presented** in Table 4 and the

PROVIDE and REQUIRE: *Provide* collocates with some kind of data allowing a better understanding of a problem (*an example, information, some understanding, an easy solution, accuracy*):



(91) ensembles would **provide** more information as to the

or with words indicating some quality that is required (*densification/density, strength, absorption coefficient, the required pressure*):

(92) molecular weights **provide** higher green strength when

(93) processing, which **provides** molecular level homogeneity

(94) to approxi. 1375 °C, **providing** sintering resistant pore materials

a common phrase is *provided in solution X*:

(95) Wacker had been **provided** in solution (50 wt%) by the

Require is used with *in* to indicate a stage or phase; with *to* and *for* to introduce an end:

(96) precise control is **required** in every production stage

(97) homogeneous mixing is **required** for consistent feedstock

(98) and research are **required** to compare the performance

Require is used in the passive voice when something has to be done to the subject (*time, experience, conditions, a few castings*) or is needed so that an aim is achieved:

(99) a few castings are **required**, seems to be the biggest

REPRESENT: The verb *represent* is used to exhibit or perform different kinds of (image) information provided in the articles. It is used to show a thing, to depict some kind of data, to exemplify, and collocates with *figure, table, data, parameter* and *slope, peak, broken lines, curves, etc.*:

(100) and broken lines **represent** body (C) with 0.96 mm and

(101) and R parameter is **represented** in Fig. 1 which shows

(102) Solid lines **represent** transmittance curves of body A



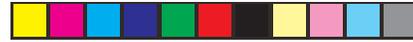
4. Conclusion and pedagogical implications

a) The data collected from the examples in our corpus may be used as background information/knowledge for teachers. This means that when students ask a question regarding the verbs we have analysed we are prepared to provide specific information regarding specialised texts or to include them in a lesson when we consider it interesting or necessary. By analysing specialised corpora our criteria for the selection of concepts to be covered in class improves considerably.

b) The collection of words from the corpus allows us to observe explicit rules for the use of, for instance, near synonyms or related words (heat vs. sinter; allow vs. permit; etc.). Many times the ESP teacher is unaware of the use of such words which may cause problems or doubts to our students. By the use of corpora these data become visible and the teacher/researcher is somehow forced or led to investigate the behaviour of particular words.

c) Semantic prosody may be included in specialised dictionaries, thus providing the student with appropriate information. We have seen how, for instance, the tendency is for a *crack* to be *caused* or something *leads to cracks* and in any case *cracks will occur* but will not be *made* and they do not *appear* either.

d) We have created our own classroom material based on the most frequent verbs and their patterns of use in ceramic research journals. We are not just explaining and working with a language feature in general, but with *the* language features which are recurrent in the specialised texts and which our students may run into. Following are some classroom activities based on the information obtained after our corpus analysis.

**Example 1.** – Complete the missing words using the clues:

In an experiment d_ _ _ are
information is

observed
obtained
pro_ _ ded

Values and parameters are

det_ _ _ _ _ ed
repr_ _ _ nted

c_ l_ _ _ _ _ ed via / using equations
obt_ _ _ ed
ob_ _ _ _ ed

shown

coefficients are

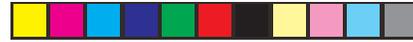
co_ _ _ dered

and results are

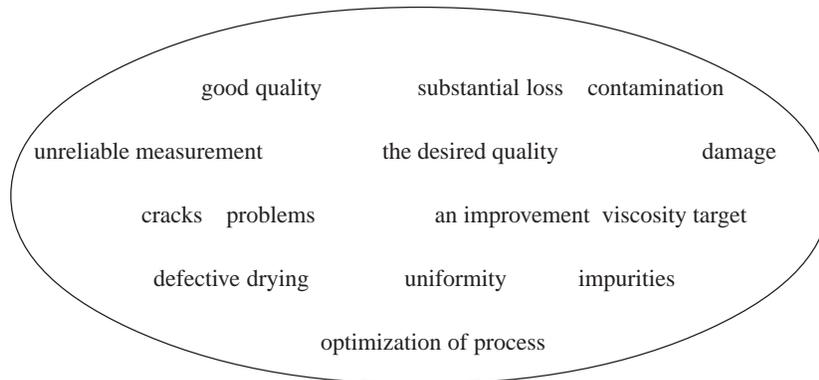
pres_ _ ted

Example 2. – Complete the following sentences using prepositions (preposition meaning and use can be explained in context and we may provide a number of examples for each use, trying not to make it just a “guessing” exercise for good memory):

1. Samples were heated __ 2.5°C/min __ 1835°C. (at, to)
2. Thermal conductivities could be further improved __ optimizing the sintering cycle. (by)
3. Parameter R_t was calculated ___ equation (1). (via)
4. Composites can also be prepared ____ mullite ZrO₂ glass powder. (from)
5. The feedstock was mixed __ 180rpm __ 120°C. (at, at)
6. etc.



Example 3. – The following words and phrases describe products/materials. Write each quality under the verb they may usually appear with. Some of them may appear under more than one verb:



CAUSE	ALLOW	PERMIT	PRESENT	ACHIEVE	OBSERVE
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
etc.		

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