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The Scientific Language of Mathematics Teachers in Teacher Education Activity

A Linguagem Científica de Professores de Matemática em Atividade de Formação Continuada

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Abstract

This research analyzes the Scientific Language (CL) in texts written by math teachers in a teacher education activity with Mathematical Modeling (MM). The data were compiled by questioning 19 teachers who teach mathematics in the final years of elementary and high school, participants in a continuing education project. To analyze the use/appropriation of LC of teachers and the contribution of ideas of their linguistic capacity, it is based on Halliday and Biembengut and evaluates: conceptual appropriation, lexical aspects, nominalizations and style of textual sequence. The results indicate that these teachers, in general, have conceptual mastery of MM. Although they use lexical items, referential terms and reduced grammatical metaphors, they write their texts with varied styles predominating narrative versions of description and/or explanation. It is concluded that although there has been a high level of conceptual appropriation, they have little linguistic mastery of LC.

Keywords: Teacher Education; Written language; Modelling in Education.

Resumo

Esta pesquisa analisa a Linguagem Científica (LC) em textos escritos de professores de matemática em tarefa de formação continuada com Modelagem Matemática (MM). Os dados foram constituídos mediante questionamento a 19 professores que lecionam Matemática nos anos finais do Ensino Fundamental e no Ensino Médio, participantes de projeto de formação continuada. Para analisar o uso e a apropriação de LC pelos professores e o aporte de ideias de sua capacidade linguística, pauta-se em Halliday e Biembengut e avaliam-se: apropriação conceitual, aspectos léxicos, nominalizações e estilo de sequência textual. Os resultados indicam que esses professores, em geral, possuem domínio conceitual de MM. Embora utilizem itens lexicais, termos referenciais e reduzidas metáforas gramaticais, escrevem seus textos com estilos variados, predominando versões narrativizadas de descrição e/ou explicação. Conclui-se que, embora tenha ocorrido elevado nível de apropriação conceitual, possuem reduzido domínio linguístico relativo à LC.

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Introduction

The teaching and learning process occurs through the use of different languages: verbal and nonverbal, common or scientific language. The Scientific Language (LC), a semiotic system characterized by its dense and complex structure materialized in lexical-grammatical and semantic aspects (Halliday, 1993b; Halliday & Matthiessen, 2014), however, still falls short of what could be done in school spaces, whether orally or in writing. Their mastery by both teacher and student is indicative of cognitive development, essential in school life and in the formation and (re) elaboration of knowledge. Thus, teacher guidance is essential for students to become familiar with the different forms of language, both oral and written, especially scientific.

In school spaces, however, oral language is still privileged in the exposition of contents and discussion of themes. Teaching takes place much more through orality and with an upward predominance by the teacher over the years of schooling (and for knowledge transfer) (Sutton, 1992). Similarly, the use of writing, stands out above all as a means of obtaining students' evaluative results at the end of a process, differently from what Hand, Lawrence and Yore (1999) point out when advocating the use of writing strategies to learn scientifically throughout the process.

Rowell (1997) and Rivard (1994) emphasize that writing has been used more as a means of communicating knowledge than for (re) elaboration of it. In the classroom, the use of this type of language is usually presented for different purposes: (i) the teacher, in the statements of activities/questions, schemes or summaries; (ii) the student, in the process records, and generally in a 'mechanical' manner, reproductive in function of the demand of the activities imposed by the teacher. The student in this process ends up using the exercise of this language more than the teacher, being most of the time, not for the art of arguing as Robertson and Graven (2019) argue.

For Rowell (1997) and Rivard (1994) it is essential that teachers know the forms of written communication and that they mediate the process of producing students' texts in the classroom in a scientific way; they should guide them to 'balance' the style of language and the ideas expressed in the texts, as linguistic requirements in oral form are different in writing. Therefore, it is necessary to provide students with the 'transition' between the simpler and more common 'linguistics' of speech, the more elaborate and dense writing, because' the use of writing is important to refine and consolidate these new ideas with knowledge. Moreover, writing seems to increase the retention of knowledge co-constructed over time" (Rivard & Straw, 2000, p. 566).

In conducting this process, according to Driver, Asoko, Leach, Mortimer & Scott (1999) and Fang (2004), teachers (more experienced) use language of their domain to mediate educational practices and provide opportunities for the appropriation of LC. In addition, they encourage students to perform tasks and other actions based on their language

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mastery. And, people who do not understand the potential meaning of extended and complex noun phrases characteristic of LC are unlikely to use them effectively in their own writing. However, it is assumed that the teacher can only give an opportunity to such activities when he himself knows and expresses in LC, because for teachers who in training and beginning of professional practice have never learned to argue, they may feel unprepared to teach argumentation and LC (Gabel & Dreyfus, 2013).

In this sense, we believe in the need for the integration of strategies mediated by writing in the spaces of formation (continued) not only to favor a more reflective and investigative attitude about the practice itself (Alarcão, 2010; Zabalza, 2004), but to that the use of LC in educational practices improves students' LC and favors their learning, because according to Planas, Arnal-Bailera and García-Honrado (2018), there are no ideal teacher lectures in the classroom, but there are more favorable ones in order to produce and communicate certain ideas and provide opportunities for student learning. After all, it is up to the teacher to "help students improve their language proficiency in the mathematical discourses needed, for example, to explain, reason, argue, and defend their thinking" (Robertson & Graven, 2019, p. 4).

Given these considerations, the appropriation and use of LC by teachers may become a contributory indicator for the mediation of LC educational opportunities in the classroom, also in the curriculum component of mathematics. This is because, when working with Mathematical Modeling (MM) considering it as an opportunity for teaching with research, the teacher mediates the teaching and learning process using various forms of languages, not just mathematics. This is because the process culminates in the presentation of a text containing what was studied and discussed for the resolution of the problem situation, based on data and information gathering. This means that the student should argue about his choices and outcomes (Robertson & Graven, 2019). Thus, a work with MM presupposes not only the use of formal mathematical language, but also other languages, because the student learns more than just mathematics, such as Portuguese Language, Science, Geography, among others (Biembengut, 2014, 2016). As well expressed by Carvalho (2013, p. 2789), it is argued, "it is no use investigative activities in the hands of teachers without the necessary skills to promote scientific enculturation". Therefore, it is pertinent to investigate such skills in teachers who are discussing and implementing MM practices in the classroom.

It fits with Carvalho (2013) and Sasseron and Carvalho (2008) that it is the interactions between students, and between teachers and students, that should provide conditions for scientific argumentation. It is believed that working with MM, understood as a research teaching method, follows the same principle. However, because of little progress in this direction, it is also necessary to verify whether teachers can achieve this.

Thus, written language can provide ideas of teachers' linguistic capacity, and can characterize the style/type of language that they may be encouraging and intending to be used in the expression of the MM process by their students. From the considerations, the question is: **The teachers of Basic Education mathematics, when expressing their understandings about Modeling (Mathematics) in Education, use in what way the LC?** This question

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guides this research, which has as its premise: the language used by the Basic Education mathematics teacher, when expressing/writing his conceptions about certain knowledge, expresses his linguistic capacity in relation to LC, and this fact may be implicative in the classroom in the way it accepts, promotes or validates the use of its students' written language.

It is worth stating that in the preliminary literature review, no studies on the LC of teaching math teachers were identified. Oliveira et al. (2009) present a proposal for teacher training for research-based teaching of LC, however, without data or indications whether these teachers conduct teaching and learning as indicated, or whether they express themselves in accordance with the proposal. The same was observed in Carvalho (2013), where notes of some conditions of dialogue between teachers and trainers for a teaching that promotes scientific enculturation. In this, the trainers worked to build the scientific language with those involved in almost every meeting. Therefore, this study can provide, from the continuing education developed with mathematics teachers, information about how these teachers of mathematics of Basic Education use the LC, thus demonstrating their mode of scientific enculturation.

It is worth noting that continuing education is advocated from a professional development perspective, which involves a continuous movement of transformation and constitution of the subject within a specific professional field so that teachers “learn and develop professionally through participation in different practices, processes and contexts, intentional or not, that promote the formation or improvement of teaching practice” (Fiorentini & Crecci, 2013, p. 13).

From the above, in the search for answers to the guiding question, we present part of continuing education meetings with mathematics teachers, by analyzing their answers to a question after the development of a pedagogical workshop, and theoretical study of MM in Mathematical Education? Guided by the following questions: i) do teachers in their texts demonstrate mastery of the concept of MM in Education? ii) how does your writing express use of LC? Thus, the research aims to analyze the LC in the written texts of mathematics teachers in task of continuing education with MM in Education.

Theoretical framework: Language (Scientific)

Language, initially conceived as a means of thinking and reality, has its concept changed from Halliday Functional Linguistics (1993a, 1994, 2001), Halliday and Matthiessen (2014) and Halliday and Hasan (1989). Language is understood as an 'instrument' involved in the activities of negotiation, construction, organization and reconstruction of human experiences. It is one of the semiotic systems that constitute a culture. In addition to being conducive to meanings, it is the main system/resource for producing them; allows your users to interact to coordinate their activities while reflecting on their different interpretations of the experience and sharing them. Meaning is encoded in verbal language using lexicogrammatically system, vocabulary/phrases (Halliday, 2001).

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Thus, Silva (2019) points out that the classroom teacher needs to understand that the new role of language goes far beyond a simple mode of information transfer and indicates that "students need to participate in their acquisition of scientific language" (1), being acquired more effectively by problematization rather than memorization, and it is up to the teacher to have sensitivity and recognize how his students are perceiving this language. After all, Language and Science come together, because learning Science is learning a language created to encode, expand and communicate scientific knowledge. What needs to be understood is that learning the specialized language of science is the same as learning science and that "language is the essential condition of learning, the process by which experience becomes knowledge" (Halliday, 1993a, p. 94).

> [...] in science, language is a fundamental tool. It is used to classify, decompose and explain, and narrate the investigations that form the basis of a scientific worldview. It follows that being illiterate in science must be denied access to a crucial aspect of its technology. [...] Science cannot be understood 'in its own words'. It has evolved into a special use of language in order to interpret the world in its own way, not in common sense (Martin, 1993, p. 20)

In this sense language is a system of signs through which people from the same community/group relate, understand and express themselves (Halliday, 1993b). Used for communication of technical and/or scientific content, the LC makes use of proper linguistic standard for the argumentation, clarity in the exposition and objectivity in the proper expressions of the treated subject. These are historically developed characteristics that differentiate it from the more general semiotic system: scientific textual discourse is a construction that enables the dissemination of knowledge through its own language, distinct from the others by lexical, syntactic characteristics and complete textual configuration. In order to exemplify linguistic aspects evidenced in scientific texts, Halliday (1993b) studies on difficulties presented by students whose native language is English, or those who learn English as a second language, are: interlinked definitions; technical taxonomies; special expressions; lexical density; syntactic ambiguity; grammatical metaphor and semantic discontinuity. Silva (2019) points out that the nominalization process and the grammatical metaphor, for example, are important sources of difficulties for the acquisition of scientific language.

LC requires technical terms or expressions to name entities that are characteristic of the same area/theme or field of science and should not be expressed in terms of common sense language. In addition, the density of information in a given passage of text, the lexical density (Halliday, 1993b; Fang, 2004), determines the proportion of lexical items with real meaning within a sentence, giving it a high informational density. Such density can be determined in two ways: (i) number of words with meaning in the sentence (Halliday, 1993b); or (ii) percentage of words with meaning in the sentence/text in relation to the total (Eggins, 1994).

Lexical density is a byproduct of grammatical metaphor. This occurs when processes or phenomena (actions, events, mental processes or relationships), usually expressed through verbs, are coded as 'things or objects' and replaced by nouns, with the substitution of one

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grammatical class for another. Nominalizations, in addition to creating technical terms and synthesizing/systematizing information in detail, allow us to relate more than one process or phenomenon in a single sentence, as occurs with cause-effect relations. Halliday (1993a) illustrated an example with an excerpt from the Newton Treatise on Optics text: "These colors indicate **a divergence and mutual separation of these heterogeneous rays through their unequal refractions"** (p. 168). Metaphors also allow the formation of long (bold) and complex nominal groups (Martin, 1993; Halliday, 1993b).

A text written with LC characteristics, according to Halliday (1993a, 1993b), Lemke (1998, 2002), Fang (2004, 2006) and Mortimer (2011), is a distant, non-engaging text that is difficult to read and understand. It does not particularly appeal to students who prefer to write other types of sequences, the "narrative" ones. On the other hand, common language predominates narratives that report linear and sequential events with verbs in the past tense. In LC the processes usually expressed by action verbs (in the present tense) linked by words that express relationships (to be, to symbolize, to possess, to imply), give the LC the structural character and the result are linked and articulated texts, which start from information and continue establishing relationships between nominal groups. The emerging texts then refer to descriptive, argumentative or explanatory[5] textual sequences.

Textual sequences, a set of words that enable a text to have certain characteristics, are understood by Bronckart (1999, p. 118) as "relatively autonomous structural units, which integrate and organize sentences, can combine several propositions. The linear organization of the text can be conceived as the product of combining and articulating different types of sequences." According to Adam (1992), it is usual for a text to integrate several sequences. They correspond to five types of "macrosmatic relations memorized by cultural impregnation (through reading, writing and text production) and transformed into a scheme of recognition and structuring of textual information" (Adam, 2008, p. 204): narrative, descriptive, argumentative, explanatory and dialogical (Bronckart, 1999).

Methodological procedures

This interpretative qualitative research (Bogdan & Biklen, 2010) was conducted with a group of practicing mathematics teachers in Basic Education (Final Years of Elementary and High School). This is a case study (Bogdan & Biklen, 2010; Yin, 2005) because it analyzes an experience developed in a specific context, which sought to investigate the scientific language of the participants. The study included 19 mathematics teachers (16 women and 3 men), with an average of 16.2 years of professional practice, working in the state education network. Of the three university teacher educators, one of the authors of this text conducted the process.

[5] The order presented represents the level of complexity of the scientific language: the descriptive (simpler), the argumentative (with few variants) and the explanatory, which has numerous subtypes: cause-effect, enumeration, specification, problem solving. Each type (or subtype) represents different logical operations that take place in the producing subject of the text.

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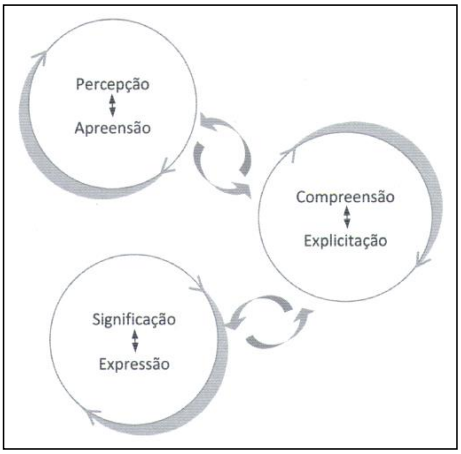
Since 2015, the group has allocated space for study on Modeling (MM and Modeling in Education), trend of Mathematical Education, considered as a teaching and research method, whose focus is teaching (Mathematics) with research. In this conception, the student is urged to raise questions and data about the theme/subject, formulate a problem and its hypotheses and then formulate a mathematical model to, in the final stage, solve the questions raised from the model, evaluating it then. The procedures involved in the MM process should allow the student to learn mathematics from subjects in other areas while learning to do research (Biembengut, 2014, 2016).

> gives each student the opportunity to: understand a situation and its context; know the *languages* involved, including those in mathematics and/or science, which enable them to describe, represent and solve a situation; and interpret/validate the outcome within that context - *learn the art of modeling, researching*. It also allows the student to taste and interest in some area of knowledge, realizing that these contents then learned hold them as fundamentals or even 'important' means. (Biembengut, 2016, p. 178).

The training was based on the assumption that the experience of the process of MM followed by the theoretical study and reflection of theory/practice, enables them to be confident to adapt the process to the teaching of mathematics and implement it (Scheller, Bonotto & Biembengut, 2015). Therefore, it was opportunity for these teachers to learn *'through and about'* modeling using the method experience and theoretical support, developed from the perspective of reflection *'in'* and *'for'* pedagogical action.

In this context, the data were obtained by applying a question to the 19 teachers, held at the end of the fifth training meeting on Modeling in Education, in 2017. The answer to the question took place individually and complementing the data collection instruments. Filming and audio recordings of the meetings were also used.



Look at the next figure that represents the modeling process. Write a short text to explain this process.

Fonte: Biembengut (2014, p. 23)

Figure 1 - Questioning asked to mathematics teachers participating in continuing education
Source: Prepared by the authors

The purpose of this questioning, illustrated in Figure 1, was to provide teachers with space for conceptual expression of the Modeling process experienced and discussed, as well as to identify LC characteristics expressed by them. The elaborated text also examined the

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meanings expressed, highlighting the conceptual formation and the conceptual errors of the trend. For this, we analyzed the texts around the concept of Modeling in Education of Biembengut (2014, 2016) and its three stages. The scheme illustrates the movement between the modeling phases, which are not disjunctive, but a constant 'come and go' movement. It is noteworthy that the scheme had not been previously viewed by teachers or discussed in the training, although it has subsidized enough information for a mental construction of it. It is also noteworthy that it was not worked or discussed about scientific language, and this study is a future pretense of the project.

For the concreteness of the data the writing was used, because it can be considered as revealing of a coherent and significant conceptual system. It was considered in this research that writing reveals the expression of teachers' thinking of the Modeling process, grounded in the social context in which it was elaborated and constitute d characteristic data of the use and appropriation of LC of mathematics teachers in training.

For the analysis of the texts are considered as units of analysis each of the sentences (or part) that compose the text and express an idea belonging to the process. Based on the theoretical assumptions of Language, a priori four categories were chosen for analysis, as shown in Table 1. The first concerns the conceptual domain of MM that teachers must have in order to insert the teaching method into their practice and is due to of the theoretical references. The others refer to the LC. Therefore, the categories emerged from the references considered in the text.

Table 1 - Categories for scientific language evaluation of texts prepared by teachers.

Categories	**Description of categories**
Conceptual appropriation	Refers to the domain level of the Modeling concept and process phases.
Lexical Aspects - Referential Terms and Lexical density.	Referential terms - specific expressions or terms that refer to the object of study - Education Modeling process - which are easily understood and recognized by those who are knowledgeable about the subject.
	Lexical density - refers to the proportion of words that have real meaning within a sentence. They are nouns, adjectives, most verbs and some adverbs (essential to mean in the sentence); auxiliary verbs, prepositions, articles, conjunctions, pronouns and some adverbs are excluded.
Nominalizations and Metaphors	Substitution of class or grammatical structure by another in the search for construction of logical arguments, allowing the formation of long and complete processes. To analyze them, besides fixing in the nominalizations, we observe the verbal processes - time and textual language of speech; and relationship between the parts of the prayer.
Text composition style / text string	It is the set of elements (words) that enable a text to have certain characteristics. They are abstract schemas, superstructures or global structures, which can be alternated or intertwined throughout the text, and involve a series of linguistic characteristics: narrative, descriptive, argumentative, explanatory and dialogical (Bronckart, 1999).

Source: Based on Halliday (1993b) and Bronckart (1999), except the former.

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From the establishment of these categories, the written text of each teacher was read, coded as P1, P2, ..., P19, as well as divided into parts corresponding to each of the Modeling phases (Biembengut, 2014; 2016). 1st - Perception and Seizure; 2nd - Understanding and Explanation; 3rd - Meaning and Expression; as well as the parts of the texts referring to general aspects of the process. Then, within the divisions, we identified the units of analysis that were recorded in a spreadsheet containing quantitative values of each item that composed it. These, in the end, were summed obtaining absolute values and, if pertinent, the corresponding percentage. The units were organized and relationships between them were established in the categories. Emerging understandings were communicated in descriptive and interpretive texts that express the meanings obtained in the analysis process. Interpretations were elaborated based on the theoretical assumptions of LC and MM and previously developed studies described above. To evaluate the LC in the teachers' writing it is considered that a characteristic text of this kind of language should: (i) express conceptual domain of the theme; (ii) have referential terms and considerable lexical density harmoniously distributed throughout the text; (iii) contain long, dense sentences resulting from grammatical metaphors; (iv) prevail mixed predominant textual sequence, except narrative predominance.

Results and discussion

The experience and reflection of teachers on the process of modeling (Mathematics) enables the reconstruction of knowledge about the possibilities of doing science in the classroom. Writing about it illustrates the use of language other than orality. This is because, as stated by Halliday (2001) and Vygotsky (1987), written language is more structurally elaborated than spoken language, being possible to think, create/recreate and write/rewrite expressions. Therefore, the writing of the Modeling process performed by the teacher must contain expressions, specific terms related to Modeling, so that the terminology (lexical-grammatical) has meaning in the context in which it is being used and in the subject matter. The results of the analysis of this writing are contemplated below, along the four categories already indicated.

Conceptual Appropriation

The analysis of the writing of the 19 texts shows, according to Table 1, that the concepts of Modeling in Education for teachers are two: research method and teaching method with research.

Table 1 - Teachers' conceptual appropriation regarding modeling

Concepts	Number of texts	Texts where there are general considerations of Modeling Movement
Modeling as a Method of Search	10	5
Modeling as a Method of Research Teaching	6	1
No conceptual domain	3	0

Source: Prepared by the authors

The protocols that describe Modeling as a **research method** in teaching do not refer

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to the area of knowledge or the curricular unit that can be used. Already those who report to the process of modeling as a **teaching method with research** there is reference to mathematics. Of the teachers, 16 evidence conceptual appropriation of modeling at different levels, and only in one there are no considerations about the third phase of the process. The evidence of modeling as a teaching method with research in six of the texts is due to the fact that training provides space for adapting the research process to "teaching with research", with the elaboration and execution of proposals for MM and modeling for teaching. This highlights the incorporation of the concept arising from formation, at least in theory.

Another important factor regarding conceptual appropriation relates to the meaning these teachers give to the movement contained in the scheme. Five of the six that highlight in the text considerations of the process as a whole and not just the one corresponding to each phase of Modeling, conceptualize **Modeling as a Research Method**, as illustrated by protocols of P18 and P8, respectively: *"[...] the various processes interrelate, it is a process of coming and going"* and "*The modeling process involves steps similar to scientific research*". What may represent the fact that only six of the teachers issue considerations of the process as a whole? There may be two reasons: (i) relationship between thought and reflection, functions of language for Vygotsky (1987); (ii) teaching / curriculum design.

- With regard to the first reason, the considerations indicate that writing begins (P1 and P18) in these cases after analysis of the schema and not only of the sequential parts illustrated therein. Moreover, it relates to something greater than just what happens in each phase, going beyond the unsaid, as P8 earlier, by expressing general considerations about the process. Already the protocol "*It is a process that involves constant reflection, back and forth thinking*" (P8), recorded at the end of the text, expresses the power of synthesis and argumentation of the student-teacher after reflection and expression of the content of the scheme. This is because "explaining, or writing analytically, requires a reflexive logical position that encourages students to refine their thinking, thereby increasing their understanding of the subject studied" (Oliveira & Carvalho, 2005, p. 349).

- Regarding the second reason, the little emphasis given by others to the process may be characteristic of the conceptions and perceptions of such teachers: (i) the process of teaching and learning or of fragmented or compartmentalized curriculum component, so that they first visualize the parts which form a whole. In expressing general considerations, teachers give evidence of integrated curriculum design and mathematics 'as an existing part of' and not just 'a constituent of' curriculum. Understanding and expressing only phases and not aspects and reflections of the whole process shows a simplistic and fragmented view of teaching, which would be composed of parts.

Lexical Aspects - Referential Terms and Lexical Density

Referential terms are also an essential part of LC. The analysis identifies the presence of terms other than those in the scheme provided to teachers. The initial terms subsidize the expression of other referential supports for writing. As continuing education is based on the principles Modeling of Biembengut (2014; 2016), although other theoretical conceptions are

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discussed, the main references are identified, according to each phase of the movement, as shown in Table 2.

Table 2 - Main references in the written texts about the Movement between the phases of MM

Modeling Phase	References	Text Frequency
Perception and Apprehension	Theme / fact / phenomenon	14
	Problem (situation) / problematization	14
	Familiarization / Observation / Interaction	10
Understanding and Explanation	Formulation of the problem situation	10
	Hypotheses	01
	Model Formulation	10
	Problem resolution / problem situation	09
Meaning and Expression	Solution Interpretation	07
	Validation	07
	Expression of Results	03
General Process	Stage / Phase	04
	Process of coming and going / interrelationship between phases	03
	Reflection	01

Source: Prepared by the authors

According to Halliday (1993b) and Fang (2004), mastery of technical vocabulary indicates the level of grammatical resource required for accurate and effective communication of scientific ideas and knowledge on the subject. The presence of terms derives from the meaning given by the teachers to each of the stages of the process or of this in general form; not being used in isolation or explained in the details; contribute to the process expression although the writing did not show complex taxonomic constructions.

The presence of referential terms evoked in a larger quantity of texts in the first phase of MM may be representative of the relevance given by the teachers to this phase and also of the relative learning of the process. The context of the training may be responsible for this highlight, since the other phases were not so explicit during the meetings, especially the expression of the process in the third phase. Regarding this, the lack of mastery of the meanings of referential terms indicates a lack of understanding of the scientific text in Fang's view (2004).

Table 3 - Lexical references of the texts of the teachers and researcher/author of the theory

Author of the text	No. of sentence	Words / Phrase	Items / Phrase	Lexical Density (%)				
				Phase 1	Phase 2	Phase 3	All	Average
Researcher	11	10.3	5.6	55	61.1	55.6	46.2	54
Teachers	3.1	18.7	8.5	45.8	45.5	44.3	45.1	45.2

Source: Prepared by the authors

The frequency and presence of referential terms are related to the length of the written text and the level of meaningful words it has (Halliday, 1993b). In the case of teachers, the length of textual productions ranges from 33 to 78 words (58.4 on average), with lexical

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density of 45.2%, both lower than those of the author of MM theory, Biembengut (2014). This shows that the extent of the teachers' writing was reduced and with low density, which characterizes a poorly structured language and devoid of meaning to what MM becomes.

The analysis of Table 3 shows texts with reduced number of words and also words with meaning; both contributing to the movement being expressed synthetically, with reduced lexical items and, consequently, not very dense. The phase of the most expressive Modeling process in quantitative terms was the first phase, presenting the largest number of words, lexical items and lexical density percentage (20 words and 9.2 lexical items). It indicates that to express the whole movement, they use more space (words) in writing with considerations regarding the first stage, reducing until reaching the third stage, with 35% less. It may indicate that the teacher's attention is focused on the phases that they most dominate or that were most expressive during the training. The lexical reduction curve along the writing of the MM process was opposite to the one perceived in the researcher's writing, which allocates more room for inferences in the third phase, a step that is essential for the expression of knowledge and indicative of learning. It is also found that the lexical density decreases as the teacher and the author of the theory present examples, as they come closer to the structure of spoken language. The fact that lexical density is not constant and may vary from one part of the text to another was highlighted by Halliday (1993) in his studies.

The sentence structure is related to referential terms and lexical density, consequently, to nominalizations. For this, in a text, according to Eggins (1994), a sentence typically consists of participants (nouns), processes (verbs) and circumstances (adverbs and propositional sentences). In these conditions, from Halliday's studies (1993b) it is highlighted that in scientific texts analyzed by the author, the sentences, on average, contain 20.3 words[6] (18.6 words in English) and high and complex informational load, therefore long, structured sentences. Given this information, it can be seen in the teachers' texts reduced number of sentences: 3.1 long sentences, while the researcher expounds the theory regarding movements in 11 short sentences. The number of words in teachers' sentences, similar to referential terms, is also descending throughout writing. Moreover, the sentences of the texts do not contemplate the structure described by Halliday (1993b) and Eggins (1994).

Text close to the structure described by these authors is that of P6, with the largest number of sentences (five in total) among all texts: 11.6 words/phrases and 6.2 lexical items/sentence. This text has a density of 53.4%, followed by P8 (3 sentences, 15 words and 8.3 items/sentence) with 55.3%. These values illustrate that, in the case of these teachers, a well-structured and dense text requires coherent use of the grammatical structure, although the average of 18.7 words/phrase is close to the values obtained by Halliday (1993b). Far from these values is the text of P2, which despite having four sentences, has a low number of references and a density of 34.3%, which is far from the LC standards.

Regarding lexical density, according to Halliday (1993b) and Halliday and Matthiessen (2014), in the expression of the same fact/theme/subject in common sense oral

[6] Number of words obtained from English to Portuguese translation.

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language, there are usually two to three lexical items in the sentence. When language is more planned and formal this value rises; and when using written language, the number rises from four to six items. Already in scientific writing this value will be higher, "about 10-13 items/sentence[7]" (p. 76), because in this style of language there is a condensation of two or more sentences expressed in spoken language. Translated to Portuguese language the density drops from 65% to 59%, remaining still high. From these considerations it can be seen that the number of information density per sentence in the texts is very low (8.5 items/phrases and 45.2% density), but it goes beyond the common and written language limits described by Halliday (1993b) and Halliday and Matthiessen (2014). In texts, the number of appropriate lexical items does not imply a guarantee of characteristic texts of LC, as they are not dense texts.

The following are examples of illustrative fragments with: (i) high density - *The **modeling process involves steps similar** to **scientific research (P8). Meaning** and **expression: interpretation** of **results (P6);** and (ii) low density - The **expression is born** out of **nothing,** but from the **visualization** of what was **accomplished* **(P2).** *This whole **process serves** in the **end** the **student** can **validate** all that he **built** himself (P15).* According to Halliday (1993b), as the density increases, text passages become more complex and difficult to read and understand. However, in the texts of teachers who use long sentences, writing in this way does not guarantee the referred increase in density and level of complexity.

Nominal processes - nominalizations and metaphors

In scientific writing, nominalizations increase the text's lexical density by increasing the number of processes and the level of complexity. In grammatical metaphors there is "substitution of one class or grammatical structure for another" (Halliday, 1993b, p. 79), so that it enables the formation of logical arguments. The analysis of nominalizations and metaphors requires observation of interrelated aspects: **verbal processes** - time and textual language in discourse; the relationship between parts of prayer and; **nominal processes/nominalizations**.

Table 4 - Textual language in the speech present in teachers' texts

Textual language in speech	No. of texts	Percentage (%)
Personal	3	18.75
Impersonal	6	37.5
Mixed - predominance of personal language	3	18.75
Mixed - predominance of impersonal language	4	25

Source: Prepared by the authors

Regarding the textual language in discourse, we can see in the texts marks of personality and impersonality (Table 4). The author's degree of intervention in the text,

[7] Halliday (1993b) points out that in scientific texts the information density of fragments taken from scientific texts is 13 (of 22 words in the sentence), 10 (of 14), 13 (of 20) lexical items per sentence, average of 65%. of density. However, these same translated sections have their reduced density: 13 (from 26), 10 (from 16) and 13 from (19), i.e. 59%. Such reduction had already been identified by Mortimer (1998) and Braga and Mortimer (2003).

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distance or proximity, provides indicative of the language style used.

Neutrality, characteristic of LC, is related to impersonality in scientific discourse (Oliveira & Queiroz, 2007, 2011). Of the 16 texts, 10 bear marks of personality, perceived in syntactic constructions when teachers use first person singular or plural verbs when writing about the Modeling process. The protocol of P14 illustrates this type of language: "*From MM **we can** seek the solution of some situation that **we are** interested in. So, from what **we are** interested in, **we seek** everything **we have** for information and start investigating the possible solutions to the studied question using any knowledge or tool **we have** reach*" (P14). This construction, marked by personality, originates narrative texts (Halliday, 1993b).

The rewrite of this fragment of P14, with adaptation to the characteristics of the LC, could be: **The MM search for situation solution problem of interest starts from previous information and follows with the use of knowledge or reach tools**. For Halliday (1993b), such rewriting requires the person to reconstruct the mental image of words, since processes and events are transformed into nouns. In addition, this change in grammatical structure is resilient and needs to be learned through experience, so the name of language as a semiotic system. Both Halliday (1993b) and Silva (2019) highlight that this process is one of the main difficulties for the acquisition of scientific language. Therefore, it is up to the teacher sensitivity to recognize how students are dealing with this type of language and help them to acquire it, thus meaning the process of mediation in class.

In the process of impersonal writing prevails in third person verbs and / or in the analytical or synthetic passive voice throughout the text (homogeneity). Passive voice is useful and sometimes necessary textual organization strategy (Fang, 2004). It allows to gather information after the verb, giving a syntactic effect to the end of the sentence. It also allows the writer to achieve a certain degree of objectivity and authority by not mentioning the authors involved in the scientific process. The language contained in six (6) of the texts contains marks of impersonality through passive syntactic (use of the pronoun if) or passive analytic (use of auxiliary verb to be/to have + main participle) constructions, respectively illustrated by: (i) "*At first some problem is **defined**, usually broad" (P7); (ii) "In the perception and apprehension stage is the moment of questioning regarding the problem that will **be investigated**. Informal conversation about the subject to **be worked** on*" (P13). However, these constructs do not imply the packaging of quantities of information and processes. Mixed-language texts are identified, that is, teacher's writing oscillating between expressions related to common language and others with nominalization process resulting from passive syntactic constructions, as in a fragment of P18's text: "*In the process of perception, **we have** the formulation of the problem and familiarity with the subject **to be modeled".***

Regarding the verbal processes expressed in the third person, the LC considers its effective use to condense two processes, perceived in the texts upon the use of relation or connection verbs*: is, consists, represents, follows, validates, involves and serves*. They were used to define, classify, compare or characterize. According to Halliday (1993a, 1993b) and Fang (2004), relational process verbs are resources that the writer makes use of to

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describe/explain experiments and to establish relationships in the theorizing process. The presence of these types of verbs has a direct influence on grammatical metaphors.

However, teachers often use: (i) compound forms of verbs in the expression, unlike passive analytical formations, such as "*we need to study", "seek to give meaning", "are understanding and giving [...]", I can represent*; (ii) verbs in the gerund - *taking, constructing, perceiving, analyzing, understanding, validating and expressing;* (ii) infinitive verbs - *know, verify, demonstrate, arrive, find, understand, describe and solve*. These constructs denote action in the case of infinitive verbs; continuous action referring to something that is, has been or will be happening, reinforcing unfinished processes, in the case of gerund employment. In addition, they make the sentence over-termed and mostly unnecessary. The same is true when the teacher uses auxiliary verbs or compound tense. These cases imply a reduction in lexical density and poverty of nominalizations, according to Halliday (1993b).

As for nominalizations, the texts have an average number of 7.8 words nominalized by production and 2.5 words per sentence. The first phase of modeling contains the highest average number of nominalizations (2.5), while at the other end is the part of the texts when teachers refer to the modeling process as a whole. All 124 nominalizations in the texts come from verbs and none from adjectives or adverbs. As expected, the most cited are the scheme provided to teachers, followed by the referential terms*: solution/results (7), situation/questioning/problematization (6), resolution/results* (6). Although the scheme offers possibilities for the formation of grammatical metaphors, they are restricted and simple.

Among the nominal processes, two different degrees of metaphors are identified, according to Halliday (1993b): (i) relationship between one process and another, expressed by conjunction (10); and by relation/link verb (16). In the latter, of greater complexity, there is no significant difference when looking at the modeling phase in which they are located. The small number of metaphors shows, according to Halliday (1993b) and Fang (2004), that the construction of metaphorical texts results in alienating and non-engaging text, which does not please the students and, in this case, the teachers, and does with them produce narrative versions of science (with personal involvement and emotional responses) as in P14. When considering aspects contained in the process of formation of grammatical metaphors, texts of P8 and P14 respectively illustrate extremes of writing.

Metaphors are an important resource for describing / explaining their experiences and for establishing argumentative relationships necessary for the construction of theoretical ideas. However, difficulties in mastering these perceived linguistic resources in writing will impact the construction of scientific knowledge and effective and accurate communication of scientific information. The presence of personality in discourse and the limited number of relational verbs and nominalizations/metaphors is indicative of the teachers' limited mastery of these linguistic resources, which evidences, in general, difficulties in the written communication of scientific information concerning the movements of the Modeling.

Text Composition Style - Textual Sequence

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Writing is important for the refinement of old ideas and the consolidation of new ones, it contributes to increased retention of knowledge co-constructed over time (Rivard & Straw, 2000). By presenting certain characteristics, it consists of varied textual sequences. According to the criteria of Bronckart (1999) and Fang (2004; 2006), most teachers' texts consist of sequences in which explanation or description of the phases of the modeling process predominate in a narrativized way. The terms used in the scheme serve as referents for the use of explanatory/descriptive language by teachers.

According to results illustrated in Table 5, the textual style used by teachers in the preparation of their texts is not very different from the style used by students of Basic Education presented in the studies by Silva and Aguiar Junior (2014): predominance of narrative explanatory texts.

Table 5 - Textual style in the speech present in the teachers' texts

Text style	No. of texts	Percentage (%)
Narrative Explanation/Description	7	43.75
Description	2	12.5
Descriptive Explanation	3	18.75
Argumentative Explanation	4	25

Source: Prepared by the authors

It was observed that in most texts (9), teachers limit themselves to: (i) narrate/describe linearly only referring to the three phases of modeling; (ii) use personal language in the active voice and use of auxiliary verbs or in the gerund (constructing), which denote action (detect, search, find), factors that contribute to the reduction of lexical density; (iii) and expose their knowledge about the process with few nominalizations, as in the case of P10 where there are none of the three existing ones other than those contained in the provided scheme (process, modeling and meaning); (iv) use unclear and objective writing as expressed in the P10 fragment (hereinafter underlined) when writing about the second phase of the modeling process. Features that are close to common language illustrated in text as of P10, as follows:

> The modeling process follows steps where we initially detect the key problem or case to be worked on; <u>In this case we look for theses that explain it and we made theses to see if our ideas are variable.</u> In the end, we find a significance for the case in question, constructing a model that approximates as much as possible the raised hypotheses and reality" (P10).

It is considered that in seven texts, there is a predominance of LC, because in addition to descriptive explanatory language and argumentative explanatory style, they present characteristics of impersonality marked by passive voice, presence of higher nominalizations with the use of verbs of relationship between processes, Modeling referential terms and conceptual domain referring to movements in the Modeling process. The text of P8, previously quoted, is an example of this kind of language.

There is a direct relationship between argumentative explanatory textual sequences, higher nominalizations and expression of general considerations of the Modeling process. The same is not true when compared to lexical density. Indicates that teachers using arguments in their explanations move writing away from personal language and use reduced

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grammatical metaphors in the conceptual expression of modeling, but still with low lexical density.

Final considerations

In order to analyze the use of LC in the writings of mathematics teachers in continuing education, this study was developed. The focus was on identifying teachers' linguistic domain through the appropriation of the concept of modeling. From the results, it can be seen that: the conceptual appropriation is not homogeneous; teachers use simple vocabulary with little taxonomic complexity; use more words, referential terms and lexical density to express information related to the first phase of the modeling process; Although lexical items influence nominalizations, they do not mean the presence of grammatical metaphors in texts; narrative texts prevail with explanation and/or description.

Thus, it can be inferred that most of the 19 mathematics teachers (79%) show in their writings mastery of the concept of modeling. However, when observed their language discourse, it is clear that only 37% have linguistic ability in terms of LC and the others have reduced language. Under these conditions, assuming that the teacher only provides activities for the appropriation of LC if he knows and uses it, it is understood that they are generally not likely to use it effectively in the classroom, both in their own use as in encouraging their students. This may be indicative of difficulties in LC by students of Basic Education.

According to Halliday (1993b) and Fang (2006), the appropriation of a language is evident when one has the ability to read and write in the proper language of a scientific culture; access information and address actions characteristic of scientific culture, from reading and writing to formulating hypotheses, explaining phenomena and arguing. However, in the case of these teachers, their lack of familiarity with grammatical resources, contributes to their difficulties in understanding scientific knowledge and, consequently, in writing.

The above becomes indicative for guiding new actions in continuing education in the specific context studied and (why not?) In other training contexts, since “a research-based curriculum combined with an explicit focus on the specialized language of science will have the best potential to maximize learning and promote scientific literacy for all students” (Fang, 2004, p. 345).

Moreover, it suggests the continuity of this study as regards investigating: i) How does the work of the Mathematics Modeling teacher contribute to qualify the teachers' scientific writing? and ii) does the qualification of the teachers 'scientific writing imply the qualification of the students' scientific writing? It is noteworthy that the study by Scheller (2017) aimed to identify how and to what extent modeling contributes to the development of LC of high school students. However, the look at the Modeling process and the teachers' scientific writing was not identified in research involving Modeling and (continued) teacher training, as mapped by (Bonotto, 2017).

Thus, the investigation of such questions, besides allowing the expansion of the research theme involving Modeling and (continued) teacher training also contributes to the

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improvement of the scientific language of these teachers, in the specific and studied context and (why not?) in other training contexts.

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