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The production of explanatory scientific texts in the initial training of Chemistry teachers¹

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Abstract

Scientific explanation is essential for the production of scientific knowledge and for understanding scientific phenomena and processes. Consequently, it is necessary professional knowledge for the teaching activity, and the chemistry teacher must master it to succeed in his/her pedagogical practice in basic education. This article aims to identify and characterize the knowledge of undergraduate students in chemistry on the scientific explanation and the writing of explanatory texts. The study was carried out with 24 students enrolled in the Chemistry Practicum II course. A pedagogical test was applied with content questions related to the study questions. The results show a low domain of this teaching knowledge as well as point out the importance of the initial formation of undergraduates in the communication processes of science, so that they can think about these processes and learn to teach them in the context of scientific education.

Keywords: Writing. Scientific explanation. Professional knowledge. Chemistry education.

1 A produção de textos científicos explicativos na formação inicial de professores de Química

Resumo

A explicação científica é essencial para a produção dos conhecimentos científicos e para a compreensão dos fenômenos e processos das ciências. Consequentemente, é um conhecimento profissional necessário para a atividade docente, e o professor de Química precisa dominá-lo para obter êxito em sua prática pedagógica, na educação básica. Este artigo objetiva caracterizar o conhecimento de estudantes do curso de licenciatura em Química sobre a explicação científica e a escrita de textos explicativos. O estudo foi realizado com 24 estudantes da disciplina Estágio e Prática de Ensino de Química II. Foi aplicada uma prova pedagógica com perguntas de conteúdo, relacionadas com as questões do estudo. Os resultados evidenciam um baixo domínio desse conhecimento docente assim como a necessidade de se atribuir importância à formação inicial dos graduandos quanto aos processos de comunicação da ciência, para que possam pensar sobre esses processos e aprender a ensiná-los no contexto da educação científica.

Palavras-chave: Escrever. Explicação científica. Conhecimento profissional. Licenciatura em Química.



La producción de textos científicos explicativos en la formación inicial de profesores de Química

Resumen

La explicación científica es esencial para la producción de los conocimientos científicos y para la comprensión de los fenómenos y procesos de las ciencias. En consecuencia, es un conocimiento profesional necesario para la actividad docente, y el profesor de química necesita dominarlo para obtener éxito en su práctica pedagógica, en la educación básica. Este artículo objetiva caracterizar el conocimiento de estudiantes del curso de licenciatura en Química sobre la explicación científica y la escritura de textos explicativos. El estudio fue realizado con 24 estudiantes de la disciplina Práctica de Enseñanza de Química II. Se aplicó una prueba pedagógica con preguntas de contenido, relacionadas con las cuestiones del estudio. Los resultados evidencian un bajo dominio de ese conocimiento docente así como la necesidad de atribuir importancia a la formación inicial en cuanto a los procesos de comunicación de la ciencia, para poder pensar sobre esos procesos y aprender a enseñarlos en el contexto de la educación científica. Palabras claves: Escribir. Explicación científica. Conocimiento profesional. Licenciatura en Química.

Situating the problem of the study

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Scientific explanation is one of the most important discursive practices in the scientific community. As an epistemic practice, it is essential for the production of scientific knowledge and for understanding the phenomena and processes of science. Consequently, it is a disciplinary knowledge about nature in the sciences, necessary for the teaching activity. In this way, the Chemistry teacher must master it so he can succeed in its pedagogical practice, in the scientific education of the students.

According to Lemke (1997), science is a social process with specific forms of communication within a given scientific community. To teach sciences, therefore, to the author, is to teach the models and resources of the scientific community that allow scientific communication, from which thematic patterns are configured as networks of interrelations of scientific concepts, within a specific semantic field of area of science.

Jimenez-Aleixandre (2003) understands that to learn sciences is also to appropriate the languages that are part of the scientific culture, constituted throughout the centuries and transmitted through written texts. Consequently, scientific



enculturation (CARVALHO, 2010) of students should also include activities for understanding the scientific explanations and writing of explanatory texts produced by scientists.

In science classes, students must learn to produce different types of texts, each with specific purposes. As Márquez (2005) explains, the learning of the natural sciences must be linked to the modeling activity with the production of texts of different types, which require different cognitive-linguistic abilities, and, among them, the explanation.

Different studies have shown students' difficulties to argue, explain, justify or describe in the face of certain tasks and situations that require these skills (MARQUES, 2005; CARVALHO, 2010; DUSCHL, 1998). According to Quilez (2016), the school, in general, has been delegating language learning to the discipline of Mother Tongue, disregarding the potential and the importance of communication and language in learning science and the understanding of the nature of scientific knowledge. Students should learn the language of science to understand their processes and phenomena and develop scientific thinking as part of their scientific education.

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Lemke (1997) criticizes the teaching of science in regard of communicative skills. For him, students are not taught how to speak and write using scientific language. In this way, it is not taught how to elaborate functional, oral and written scientific texts, through explanation. According to him, it shows only a complex set of skills and they are expected to deduce how these texts are written in science classes.

Several studies, including those by McNeill, Lizotte and Krajcick (2006), revealed that even after several years of science instruction, students had difficulty constructing a scientific explanation. A study with teachers carried out by Jorba (2000) evidenced difficulties presented by them to produce different types of texts. Pozo and Postigo (2000), in turn, explicit concern with the fact that, usually, do not teach students how to prepare explanatory texts, among others, when it requires mastery of this skill of "implicit" way in science classes.

McNeill, Lizotte and Krajcick (2006) have emphasized that scientific practice, such as scientific explanation, must be taught in a conscious and explicit manner in the classroom. In addition, as Braaten and Windschitl (2011), Núñez and Ramalho (2015) have shown, teachers also have difficulties in constructing scientific explanations.



Wenzel and Maldaner (2014) highlight the importance of further studies and discussions about writing in undergraduate courses in Chemistry. According to the authors, the practice of writing, in these courses, most of the time, does a little effectively contribution to student learning on the production of scientific texts to learn science, by the fact that it is more oriented towards a general writing without considering the specificities of the scientific language.

The general objective of the research was to identify and characterize students' knowledge of a Chemistry degree course on scientific explanation and writing of explanatory texts as an important skill to be developed by the Chemistry undergraduates, which may help to rethink the initial teacher training processes of this curricular component in basic education. From the general objective, we formulated the following questions that guided the study:

- a) What is it, for the undergraduates, to explain properties of the substances and the materials in the context of the production of the scientific knowledge of the Chemistry?
- b) What professional knowledge is evident in the explanatory texts produced by Chemistry undergraduates dealing with the physical properties of substances and materials?

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The scientific explanation and the ability to write explanatory texts in the Chemistry classroom

The term to explain refers to a varied set of meanings, which shows its polysemic nature. Its meanings are based on diverse philosophical, epistemological, linguistic, didactic, among other perspectives. In this work, we focus on the explanations produced / elaborated in natural sciences, since we investigate the knowledge of future Chemistry teachers about this cognitive-linguistic ability, necessary to teach the students of basic education to explain and not only be consumers of explanations ready and available in textbooks, in the learning of Chemistry.

According to Sanmartí (2007), the explanatory text is characterized by ordering certain facts according to a relationship that is, almost always, cause-and-effect. For Jorba (2000), to explain is to present reasoning or arguments establishing relationships based on a certain theoretical framework, from which the facts explained make sense and lead to modify the state of knowledge. Márquez



(2008) states that explaining consists not only in relating facts to each other and to ideas, but also in producing reasons or arguments in an orderly manner according to a cause-effect relationship.

Gilbert (1999), defines the explanation as:

[...] the ability to express the results of one's own reasoning, to justify reasoning in terms of obvious, conceptual, methodological considerations, with defined criteria and in a contextualized way, with coherent arguments. The explanation supposes mentioning the results, justifying procedures and presenting results (GILBERT, 1999, p. 27).

The explanation in the natural sciences is constructed from the relation between the observable and the unobservable, the concrete and the abstract. The observable, the phenomenon, must be related to the unobservable, that is, a level of "essence" which, as a model theory, provides a justification for why the phenomenon happens. Therefore, explaining implies differentiating the phenomenon from its essence and relating it to essence. In the structure of explanation, one must connect the phenomenon with its essence through various cause-effect relationships.

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Explanations can be considered as the means by which scientists relate observations of phenomena to scientific theories and propose causal mechanisms to understand them, predict future events or make inferences about past events, which leads to the conclusion that explanations are one of the most important discursive practices of scientific epistemology.

A contemporary stance on scientific explanation is the cognitive model of science present by Giere (1988), which allows us to interpret science as a cognitive activity related to the construction of knowledge. This model focuses on how scientific activity and communication, especially writing, are developed. In this process of producing meanings, cognitive and social factors play an essential role.

From the point of view of the philosophy of science, a fact is explained when it can be assumed from scientific laws (Carl Hempel), when it is shown as a particular case of more general laws, that is, when it includes other cases that respond to the same essence, but being apparently different (Philip Kitcher) or even when an adequate description of its causal history (Wesley Salmon) is offered.



Studies of the philosophy of science suggest that a single definition of explanation cannot encompass the diversity of information contained in an explanatory text. For Nagel (1979), there are four different types of responses that are considered "explanatory": deductive, probabilistic, theological and genetic. However, in this broad category, many explanations may be attempts to provide a specification of what happens and/or why it occurs, as Giere (1988) and Nagel (1979) point out. This general sense of what is a causal explanation is best suited to explain the physical properties of substances and materials, the object of our study.

According to Gómez (2006), explanations can be divided according to their function: a) to extend a meaning, b) to justify, c) to describe, d) to establish causalities. Norris, Guilbert, Smith, Hakimelahi and Phillips (2005) classify scientific explanations as: a) deductive, b) deductive probabilistic, c) functional and d) genetic or narrative.

Mortimer and Vieira (2010) distinguish the explanation as i) causal, ii) functional and iii) intentional. According to Gilbert, Boulter and Rutherford (1998), in line with the question we seek to answer, five types of explanations can be considered: descriptive, intentional, causal, interpretive and predictive.

In this study, the explanation is assumed as a cognitive-linguistic ability in its epistemological nature. Cognitive-linguistic abilities, according to Jorba (2000), are abilities that are activated and manifest in the production of texts, as in the case of those who demand scientific explanations. They are skills that are at the basis of the intellectual operations that are constantly carried out in the learning activity.

The explanation in the learning of Chemistry can be considered a cognitive-communicative ability, considering the dialectical unity between language and thought (VYGOTSKY, 1993). It is a cognitive ability, because it realizes (and activates) systems of thought reasoning, in the solution of certain problem situations. It is a communicative ability, in turn, because, through it, express thoughts typical of the explanation in a given communicative situation. This duality/unity is also evident/is present in the dialectical unity of the processes of internalization-externalization of cognitive activity (NÚÑEZ, 2009).

Prat and Izquierdo (2000) understand writing as a basic activity in any learning situation, because it is also part of the social communication activity, necessary for teaching and learning. In the classroom, the production of explanatory scientific texts by students favors reflection, a more refined thinking, a better



understanding of scientific concepts. Moraes, Galiaze and Ramos (2002) also highlighted the role of writing in the sense of allowing the domain of abstractions for an appropriation of a more qualified discourse.

Vygotsky (1993) grounded the importance of language in the processes of thought in establishing the dialectical relationships between thought and language. In his theory, language plays an essential role in thought processes and, consequently, in students' learning in the school context. It is a tool through which communication takes place, the elaboration of knowledge itself and the regulation of cognitive and affective processes. For him, writing is a form of language that influences the development of higher psychological functions and requires a level of abstraction different from oral language. When it comes to writing in science, there is the requirement of mastery a complex symbolic system, the scientific language. In the view of this theorist, written language is a very particular verbal function. It is the algebra of language, making it possible to access the highest abstract plane of language, which, in turn, reorganizes the psychic system.

Thus, Vigotsky (1993) confers on writing a specific role as an optimal tool for the development of the representative function of language, as an instrument mediating awareness, intellectual self-regulation, development and the construction of thought. The written text makes it possible to "go back", to review the writing, to reflect, to make analyzes and syntheses, which favors the learning.

Writing is, then, an important tool for structuring thinking and its externalization, being different from oral (speaking) language. In addition, written language enables a more in-depth development of theoretical generalization and consciousness.

Wenzel and Maldaner (2014) call attention to the importance of writing and directed rewriting in Chemistry classes as a good practice for the appropriation and signification of language and the constitution of chemical thought.

Lemke (1997) considers that, in order to obtain knowledge of science through dialogue, it is necessary to know what he calls the thematic standard of scientific content. This means that, in order to write in science, it is not enough to know only the scientific terms, but it is also necessary to combine the meanings, that is, to construct the thematic pattern in question.

In order to avoid the effect of semantic dispersion in the study (NÚÑEZ; RAMALHO, 2000), as a reference of standard for writing an explanatory text on the physical properties of substances and materials in Chemistry, we adopt the explanatory action base, proposed by Prat and Izquierdo (2000). According to



Núñez and Ramalho (2015), the Orienting Basis of Actions (OBA), in Galperin's theory, constitutes the structural element of the action that allows its planning, the direction of execution and control or its regulation. The OBA explains the model of action (what is it?) and the system of operations by which the action is performed (how it is done) but also represents the reference of the desired knowledge to be learned. In the Table 1, the OBA of the explain action is represented.

Table 1
Guidance base for writing and writing explanatory texts in Chemistry

That means?	Make it possible to understand a phenomenon, a result or a behavior for the reader.
What should be done?	Produce reasons or arguments. Establish relationships, especially cause (Why?)
Result to be obtained	A text that provides knowledge to the reader. Reasons or arguments should be referred to an object. There are enough reasons considering the knowledge that one should have.
There are cause relationships. The lexicon should be adequate, for Chemistry and the purpose of the explanation.	Colocar um título. Apresentar uma estrutura de texto que contenha problema-solução e relações de causa-efeito. Para isso, é necessário construir frases com relações causais ou expressas por meio de conectores, tais como: porque, já que, visto que, entre outros. Avaliar também a necessidade de se fazer algum esquema.
How to write the text	Put a title. Present a text structure that contains problem-solution and cause-effect relationships. For this, it is necessary to construct sentences with causal relations or expressed through connectors, such as: because, since, as long as, among others. Also evaluate the need to do some scheme.

Source: Prat and Izquierdo (2000) Adapted.

The context and study participants

The study was carried out with 24 students of a Chemistry degree course, in the context of the discipline Internship and Practice of Chemistry Teaching II. Almost all students (75%) were completing the third year of the course. 45% of the students are female and 55%, are male. 75% of the total did high



school in public school institutions. The average age is 20.5 years old. At this point in the course, all of them have already studied the specific basic Chemistry disciplines formation as well as the disciplines General Didactics and Educational Psychology. For purposes of analysis of the results, the undergraduates are identified by a code (L), which expresses the course for all, and by numbers (1, 2, 3 etc.), which identify each one of them.

Research methodology

In the study, we chose the pedagogical test (CEREZAL; FIALLO, 2010) with content questions directly related to the research objectives, whose answers may offer significant information (or their lack) in relation to professional knowledge. In open questions, it was not limited to or pre-established how to respond and no variants of answers were defined, so there was the freedom to respond according to how the question was interpreted.

This pedagogical test, developed by the researchers, was validated by a specialist in the subject and initially applied to five undergraduate students as a pre-test to test the clarity and comprehension, which allowed the elaboration of the final version. The application of the validated pedagogical evidence occurred in the classroom. Initially, we explained to the undergraduates how they should answer it, the time available for this purpose as well as the availability of space to write the explanatory text. The pedagogical test was divided into two parts. The first one contained questions to characterize the profile of the undergraduates, and the second was composed of the following questions:

A) What is it to explain properties of substances and materials in the context of chemistry as a science? B) Suppose that, as part of the scientific community of Chemistry, you must explain why NaCl is a solid that, under ambient conditions, has a high melting temperature. Make an explanatory text for that purpose.

Responses to the first open question were addressed by the Thematic Content Analysis technique. The procedures of content analysis, as explained by Minayo (2010), lead to relate not only semantic structures (signifier) with sociological structures (signified) of statements but also to relate the articulation of the surface of the statements of the texts with factors that determine their characteristics. In this way, we sought to encompass and summarize data, as well as to provide a primary description, which led to new concerns as the information was clearly exposed, which allowed a closer understanding of the object of study.



The analysis of the responses was supported by quantitative and qualitative procedures, in a complementary way. In this sense, the data were treated using the statistical technique of frequency analysis (quantitative dimension), organized into tables and then analyzed with attention focused on the peculiarities and relationships between the categories proposed for the analysis, considering what was significant, relevant or absent (qualitative dimension). The tables were analyzed in such a way as to make sense of the data and answer the study questions.

We applied the evaluation criteria developed by Jorba (2000), presented in the Table 2, for the analysis of the answers to the third question and the determination of the levels of development of the ability *to explain*, in relation to the NaCl properties.

Table 2
Criteria for assessing the ability to explain

Criteria
1. RELEVANCE Proposals, in general, are coherent and refer to the object of explanation (the properties of substances). It is expressed clearly, so that the reading facilitates the interlocutor to understand the intentionality of the author of the text. The registration of the language suits the function and the interlocutors of the text. 2. COMPLETENESS There are a sufficient number of propositions to modify the state of knowledge, which can be considered accepted by the scientific community. Propositions explicitly contain causal relationships. Utilize other language, such as layout, figures etc., to complete the text information. 3. ACCURACY Use the lexicon, taking into account: • the accuracy of the vocables according to the ionic bonding model; • the appropriateness of the vocables that have different meanings in the colloquial language and, specifically, in relation to the theoretical model of ionic bonding. 4. VOLUME OF KNOWLEDGE The volume of knowledge is adequate in relation to the level of explanation requested. 5. ORGANIZATION OF THE TEXT The text is organized according to the explanatory model, in which the facts are related according to the logic of the explanation. Causal connectors are used.

Fonte: Dados da pesquisa.



The knowledge of explanation in Chemistry as a science

Being able to establish the difference between scientific explanation and school explanation is essential for Chemistry teachers to develop discursive activities that help students understand the place of explanation in science and learning. This is, in turn, a difficulty presented by teachers who teach science, in the view of McNeill and Krajcik (2008).

In the pedagogical test, the undergraduates were asked to express what is scientifically explaining properties of substances and materials in Chemistry. The categorized responses are explained in the Table 3. As can be seen, only 20.8% of the licensees refer to the causal dimension of the explanation, that is, they relate the macroscopic level (phenomenology) to the microscopic level as one of the characteristics of the scientific basis explanation.

Table 3

Percentage of answers to the question: what is explaining properties of substances in Chemistry as a scientific explanation?

Categories	Quantity (%)
It is to show to the student why certain substances show certain properties, according to a theoretical model	20.8
Transmit what has been studied by someone	16.6
Make the student understand	58.3
Describe or pass on a knowledge or an information	8.2
Demonstrate the reasons and circumstances of why these properties	8.2
To relate, in terms of cause and effect, the microscopic level, that is, the constitution with which one observes the properties	20.8
Differentiate and identify the structure of the substance	12.5

Source: Research data.

The explanation understood as a way of showing, transmitting, comprehending and understanding were the categories that appeared the most, with a total of 91.5% of the undergraduates. This characteristic of providing an understanding of "something" has been pointed out by Ogborn, Kress, Martins and McGillicuddy (1998). Nevertheless, this understanding, for 79.1% of the



undergraduates, has a didactic dimension by the fact they confuse the scientific explanation (produced in the scientific activity) with the explanations of teachers or students in the school context, the latter characterized in the studies of Martins, Ogborn and Kress (2018).

The future teachers demonstrate that they cannot differentiate the scientific explanation from the explanation in the context of science teaching. According to Osborne and Pettersen (2011), this is due to the fact that a difference between explaining something (scientific explanation, in the context of the sciences) and explaining something to someone (using an available explanation and making it understandable to the students) is not established.

When one wants to explain something to someone, this can be done by transmitting or clarifying something that is already known, which does not occur in the scientific explanation. In this, it is necessary to elaborate an explanation of why something happens or to have certain properties, when one does not have an already elaborated one. It is important that, in the school context, students can make their own explanations based on established scientific knowledge, which should be compared with those proposed by science to attest to their truthfulness. According to Núñez and Ramalho (2015), it is hoped that not only teachers will explain the contents of science but also students will be able to construct explanations in the classroom.

This result evidences undergraduates' difficulties in the distinction between the scientific explanation and the present one in the school education. To be able to establish this difference is a knowledge of epistemological and didactic nature, essential for the scientific education of students in Chemistry.

In the following text fragments, there are ideas of the undergraduates who better reveal the meanings they attribute to the scientific explanation of physical properties and materials in Chemistry.

L2. It is to relate what we observe at the macroscopic level of the substances and materials with their microscopic constitution. Explain the properties relating to the chemical structure of substances and materials (L2, 2017).

L3. It is to use the knowledge produced so far by science regarding this subject, and explain it in order to make it accessible to the student's understanding (L3, 2017).

L8. The scientific explanation of the properties of the substances and materials, basically passes through the approach of aspects such as the composition of such substances / materials, the interactions



"present" in the substances / materials studied, variables that influence the properties of the substances / materials (L8, 2017).

L15. It consists of establishing and using theories to explain microscopically what is observed in the macroscopic, making use of models and representations to promote such an explanation (L15, 2017).

The ability to elaborate explanatory texts on the physical properties of substances and materials

The ability to elaborate the written text to explain one of the physical properties of NaCl, that is, to have a high melting temperature under environmental conditions, was evaluated in question 03 of the pedagogic test.

The analyzes of the texts produced by the undergraduates were carried out considering the criteria established by Jorba (2000). In the table 4, there are the results for the criterion of relevance of the text.

Table 4

Percentage of answers on the relevance of the text

Relevance	Correct	Partially Correct	Incorrect	Absent
The propositions, in general, are coherent and refer to the object of the explanation (the properties of substances)	29.2	37.5	33.3	0.0
It is expressed clearly, so that the reading facilitates the interlocutor to understand the intentionality of the author of the text	29.2	37.5	33.3	0.0
The registration of the language suits the function and the recipients of the text	50.0	20.8	29.2	0.0

Source: Research data.

In this table, we observed that, in general, the number of undergraduates using coherent propositions relative to the object of the explanation (29.2%) is low. This same percentage is observed for the second pertinence, which concerns the intentionality of explaining the high melting temperature of the substance.



Concerning the third pertinence, we verified that 50% of the undergraduates utilize a register of the language appropriate to the explanation and to the recipients of the text, that is, they somehow refer to the establishment of causal relations.

The completeness of the written text concerns the quantity and quality of the propositions utilized in the explanatory text. In the Table 5, it can be observed that, in general, the undergraduates do not produce texts with sufficient propositions that can account for a more complete explanation and satisfy the requirements of this type of text, considering that it is a multi-causal phenomenon. On the other hand, although there are texts of limited extent, they express simple cause-and-effect relationships, found in the responses of 54.4% of the undergraduates.

Table 5

Percentage of answers on the completeness of the text

Completeness	Correct	Partially Correct	Incorrect	Absent
There are a sufficient number of propositions to modify the state of knowledge, which can be considered accepted by the scientific community.	10.0	5.0	85.0	0.0
Propositions explicitly contain causal relationships.	54.2	20.8	25.0	0.0
Utilize other language, such as layout, figures etc., to complete the text information.	0.0	0.0	0.0	100.0

Source: Research data.

In order to explain in Chemistry, it is necessary to know how to relate its three representational levels (JOHNSTONE, 1982) in order to elaborate reasonings and written texts with adequate, coherent, complex, scientific, rigorous and convincing arguments.

Knowing the causes of a phenomenon is not an easy task, because it is a complex process, that goes from the phenomenon to its essence and vice versa, and because there are several causes for each one (NÚÑEZ; RAMALHO, 2015). It is also necessary to consider the possible consequences of a phenomenon. In addition, this knowledge implies defining or not the possibilities of using a given theoretical model, considering the limits of application of scientific knowledge.



The undergraduates, in elaborating the explanation, do not refer to the sodium chloride lattice energy as a factor that influences the high melting temperature. Thus, the responses reveal that they do not think in terms of a more complex organization of ions, as established in the theoretical model of ionic bonding, as pointed out by *Mendoça and Justi (2009)*. This difficulty was identified by *Taber (1994)* for Chemistry teachers. According to him, this is due to the fact that teachers use the octet rule as a model of the ionic bonding teaching, rather than the electrostatic model, which, according to *Coll and Treagust (2003)*, restricts the ionic bonding model to the transfer of electrons, formation and attraction of ions idea.

It is worth emphasizing that the use of several semiotic representations has importance in the scientific explanation, which can favor the processes of communication and construction of scientific knowledge. Scientific explanation expresses entities that are, often, not known.

Scientific language is a specific language, different from the language of daily life and, therefore, its teaching must occur explicitly. Learning science means learning to use the language of science correctly and consciously (*LEMKE, 1997; SUTTON, 2003*).

15 The Table 6 shows that the undergraduates do not use another language, like diagrams, figures etc. in the elaborated texts. This is a fact that draws attention to the diversity of semiotic representations that can be used in Chemistry.

Jimenez-Aleixandre (2003) emphasizes the importance of images in scientific discourse, especially in the visualization of non-visible entities. These images have their own language and, in the opinion of the author, it is necessary to dedicate time for students to learn to take advantage of their possibilities as much as possible. In turn, this type of language presents difficulties for the students, because it is related to certain scientific models.

Another key element that attests to the quality of the explanatory text is the accuracy of the words used in the text. Scientific language has well-defined characteristics: it is precise, unambiguous, rigorous, formal, impersonal, and often hypothetical. This requires, in the explanatory text, precision and appropriate use of scientific language, which, in this case, concerns the scientific models and theories of chemical bonding, atomic structure and periodic table.

The accuracy of the text is a quality evaluated in the written texts produced by the undergraduates. The results of this evaluation are shown in the Table 6.



Table 6
Percentage of answers about text accuracy

Precision	Correct	Partially Correct	Incorrect	Absent
Precision of the vocables according to the ionic bonding model.	45.8	12.5	41.7	0.0
Proper use of vocables that have different meanings in colloquial language and, specifically, in relation to the theoretical model of ionic bonding.	41.7	16.7	41.6	0.0

Source: Research data.

The practice of Chemistry as a science relates itself to activity in three levels of representation of explanation, in an integrated way. Johnstone (1982) calls these levels descriptive and functional, representational and explanatory. At the descriptive and functional level, chemists manipulate, observe and describe properties of materials as well as chemical transformations of materials through changes in their properties. To explain the behavior of substances and materials, theoretical models are used, such as atoms, molecules, ions, chemical bonding, among others. The forms of representing the constituent particles of the substances and the materials, that is, the chemical formulas and the chemical changes, in this case, the chemical equations, are the main resources at the level of representation.

A reading of the Table 7 shows that 45.8% of the undergraduates correctly use the scientific terms of the theoretical models necessary for explanation in the responses considered limited, while 41.7% do not. When they utilize the terms of the chemical language in a precise way, we verify that they are aware of the difference between scientific and colloquial language.

These results coincide with Sarda and Sanmarti's (2000) investigations regarding the lack of rigor, precision, structuring and coherence of texts written by students of basic education in science classes.

The undergraduates who do not accurately use the language terms of the ionic bond models (41.7%) make mistakes, among which the following stand out:

- confuse ions with molecules;
- assign molecular structure to the ionic compound;



- attribute the cause of the high melting temperature of the solid to dipole-dipole molecular interactions.

In Borsese's (2000) opinion, in the case of Chemistry, the language is specific, since each symbol contains a large number of meanings. Moreover, through language, not only are named the transformations of substances at the macro and microscopic levels, but they are also recorded, codified and transformed into elements of thought and communication.

These errors can be related to several learning difficulties in Chemistry, discussed by Núñez and Ramalho (2017), when they characterize the nature of chemical knowledge, the language of Chemistry and even the forms of teaching, among others.

The volume of knowledge was another criterion for evaluating the explanatory text elaborated by the undergraduates. The results of this evaluation are presented in the Table 7.

Table 7

Percentage of responses on the volume of knowledge in the text

Volume of knowledge	Correct	Partially Correct	Incorrect	Absent
The volume of knowledge is adequate in relation to the level of explanation requested.	0.0	29.2	70.8	0.0

Source: Research data.

Table 8

Percentage of responses on the organization of the text

Organization of text	Correct	Partially Correct	Incorrect	Absent
The text is organized according to the explanatory model, in which the facts are related according to the logic of the explanation. Causal connectors are used.	23.8	42.9	33.3	0.0

Source: Research data.

It was determined that the undergraduates, when writing, utilize very little the syntactic structures necessary to the explanatory text, specifically the causal conjunctions. They did not reveal to be aware of the global coherence that this



type of written text should have, an issue that has been pointed out by Márquez (2008) as a difficulty of the students in the writing of texts, in the science classes.

Scientific explanation of the properties of substances and materials should be carried out using scientific models and theories about their structure so that they can be considered a "cause" of physical behavior, considering the limits and possibilities of application of this scientific knowledge. Among the undergraduates, only 23.8% utilize, albeit to a limited extent, the volume of knowledge required, the theoretical models of the structure of the substances, in particular the ionic bonding, particle models and the crystalline structure of the substance. 42.9% utilize these models partially, but limited to the reference of ionic bonding, in which the ions are tightly bound and do not refer to the crystalline structure and its stability. Among the undergraduates, 33.3% answered incorrectly.

Those who answered correctly and partially utilized a few causal connectors, necessary to the explanatory text, which explains a small number of propositions presented in written texts. This is a difficulty pointed out by Quilez (2016), when referring to several researches emphasizing that these types of connectors need special attention in the students' understanding and use of scientific language. The texts below are representative of this analysis:

L4. The interaction of NaCl is the dipole-dipole type, this interaction being very strong and, to be broken, the crystalline reticulum of NaCl needs a great amount of energy (increase of temperature) to melt (L4, 2017).

L13. Sodium chloride has an ionic bond, causing the interaction between the constituents (sodium ion and chloride ion) to form a lattice resulting in a crystalline solid. This lattice increases the interaction by increasing the melting temperature because the energy required to 'separate' the crystals from the lattice will be higher (L13, 2017).

L20. Sodium chloride, because it is an ionic compound and has a very high crystalline lattice energy due to its organizational state has great stability, since it requires great energy to melt (partially correct) (L20, 2017).

The explanatory texts produced by the undergraduates, although the availability of space in the answer sheet, are characterized by limited answers to the question on the situation of the pedagogical test. In none of the cases, a narrative text preceded the explanation that would situate the theme, make a summary that contained the most important idea, develop the theme with new ideas or even



present a conclusion, structural elements that are part of the explanatory written text, according to Sanmarti (2000).

In the study, the findings coincide with other researches, such as that of Ebbers and Rowell (2002), Núñez and Ramalho (2015), which evidenced difficulties of students to produce explanatory texts, according to the propositions of Sanmarti (2000).

Conclusions

Knowledge concerning scientific explanation and the production of scientific explanatory texts as cognitive-linguistic ability and as a science procedure becomes a relevant professional knowledge for Chemistry undergraduates. The training of future Chemistry teachers should take into account, what Sutton (2003) drew attention to: the science teacher being a language teacher, and all science classes being language classes, which implies training to address this professional task.

The explanatory text, an important means of communication in the field of science, plays an essential role in scientific research processes. That way, because chemical education is a process of scientific enculturation of students, teachers must have an adequate professional knowledge about what is and how an explanatory text is produced.

In the research, we found that future Chemistry teachers, for the most part, consider the scientific explanation as a way for the transmission and understanding of the physical properties of substances and materials, being associated with a didactic rather than epistemological dimension. This reveals weaknesses in the knowledge of this ability in Chemistry as a science, much related to the domain of knowledge about the nature of sciences.

In relation to the ability to write explanatory text requested in the pedagogical test, difficulties were found in the quality of written texts. Although the texts are based on the relation between the structure and the property that must be explained, there are fragile propositions regarding the knowledge of Chemistry, characterized by the absence of figurative elements, as well as there is presence of inaccuracies in proper vocables of the sciences, which evidenced a low level of knowledge appropriate to the level of explanation requested. It is difficult for future teachers to construct an explanatory text in science because it



is a communicative skill that involves the cognitive and linguistic dimensions and requires not only the understanding of the nature of science but also the mastery of diverse models and theories, among others.

In relation to the organization of the text, there was also little mastery of professional knowledge in the production of logically concatenated text, structured with connectors from which property is related to essence in terms of causal relations.

This situation allows to conclude that the undergraduates present difficulties to have an adequate orientation of the action or mental model of the action to write explanatory texts as professional knowledge, in which the operations and the theoretical models necessary to the cognitive demand in question are integrated.

The results highlight the need to assign importance to the initial training of the undergraduates in the communication processes of science, so that they can think about these processes and learn to teach them in the context of scientific education.

Nota

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