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Article

Learning to construct scientific explanations: an analysis of everyday life in the Science classroom

Aprendendo a construir explicações científicas: uma análise do cotidiano da sala de aula de ciências

Aprender a construir explicaciones científicas: un análisis de la vida diaria del aula de Ciencias

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ABSTRACT

This paper analyzes how 8th graders proposed and revised explanations for a phenomenon in Science lessons. Guided by Ethnography in Education, we gathered data from observations of the daily life of these lessons and analyzed connections between texts, contexts and events. The results indicate the teacher's role on the provisional and uncertain character given to scientific explanations; the use of discussions — sometimes in groups, sometimes with the whole class — as a resource through which students validated (or not) their explanations; and the interpretations given by students to the relationships between data and explanations under construction. These resources shaped the practices of proposing/reviewing explanations, which were evidenced by changes in explanatory proposals throughout events. The study offers contributions to the research area of Science Education and implications for pedagogical practice.

Keywords: Scientific Explanations. Classroom. Ethnography in Education. Science Learning.

RESUMO

Esta pesquisa analisa como estudantes de uma turma do oitavo ano do Ensino Fundamental propuseram e revisaram explicações para um fenômeno em aulas de ciências. Orientados pela Etnografia em Educação, construímos dados com base em observações do cotidiano dessa turma e analisamos conexões entre textos, contextos e eventos. Os resultados indicam o papel do professor sobre o caráter provisório e incerto conferido às explicações científicas; o uso de discussões — ora em grupo, ora com toda a turma — como recurso por meio do qual os estudantes validaram (ou não) suas explicações; além das interpretações dadas pelos estudantes às relações entre dados e

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explicações em construção. Esses recursos deram forma às práticas de propor/revisar explicações, o que foi evidenciado por mudanças nas propostas explicativas ao longo dos eventos. O estudo oferece contribuições à área de pesquisa de Educação em Ciências e implicações para a prática pedagógica.

Palavras-chave: Explicações Científicas. Sala de Aula. Etnografia em Educação. Aprendizagem de Ciências.

RESUMEN

Esta investigación analiza cómo los estudiantes de una clase de la escuela secundaria de octavo grado propusieron y revisaron explicaciones para un fenómeno en ciencias. Guiados por Etnografía en la educación, construyeron datos a partir de observaciones de la vida diaria de esta clase y analizaron las conexiones entre textos, contextos y eventos. Los resultados indicaron el rol del docente sobre el carácter provisional e incierto que se le da a las explicaciones científicas; el uso de discusiones — *a veces en equipos, a veces con toda la clase* — como recurso a través del cual los estudiantes validaron (o no) sus explicaciones; y las interpretaciones dadas por los estudiantes a las relaciones entre datos y explicaciones en construcción. Estos recursos dieron forma a las prácticas de proponer/revisar explicaciones, lo que se evidenció mediante cambios en las propuestas explicativas a lo largo de los eventos. El estudio ofrece contribuciones al área de investigación de la Educación Científica e implicaciones para la práctica pedagógica.

Palabras Clave: Explicaciones Científicas. Salón de Clases. Etnografía en la Educación. Aprendiendo Ciencia.

INTRODUCTION

Science Education is going through a historical crisis. In times of the pandemic, refusal to wear masks, to observe social distancing, or to get vaccinated have led teachers, professors, and researchers to question their roles in facing the decline of public trust on science (Erduran, 2021). There are grown-ups advocating flat Earth, and, despite what they heard at school when they were children, they come up with their own explanations for phenomena such as the sunset, the Moon phases, and eclipses (Tang, 2021). In such a context, it does not seem enough to ensure that children and teenagers merely learn how to provide scientific explanations for certain topics, such as immunology, the shape of the Earth, or climate change.

The scientific literature suggests that, in classrooms, scientific explanations are delivered in two main ways (Braaten and Windschitl, 2011; Tang, 2021). The first and most recurrent intends to grant students access to the explanations that science has built about a certain matter. Emphasis is put on declarative knowledge, which in general means descriptive information about natural phenomena (McCain, 2015). The second one intends to facilitate the construction of scientific explanations by the students themselves. Emphasis is then put on links between explanation and evidence (Duschl, Avraamidou and Azevedo, 2021). There is a consensus in the area that the first strategy to teach explanations reveals itself limited when not associated with the second one (Duschl, 2008).

A significant part of those research studies seeks to understand how teachers can support students in proposing/revising explanations. These studies analyze instructional tools[1] designed to teach how to construct explanations driven by scientific models of explanation (McCain, 2015).

1 Examples: Decision/Explanation/Observation/Inference — DEOI Method (Van Duzor, 2016); scaffold Premise/Reasoning/Outcome — PRO (Tang, 2016); Phenomenon-Theory-Data-Reasoning — PTDR (Yao and Guo, 2017); Explanation Tool (Braaten and Windschitl, 2011).

A second group of studies focuses on the analysis of the impact of certain curriculum propositions in the explanations provided by students. These studies implement one type of curriculum and assess its potential in improving explanations in science classes (McNeill and Krajcik, 2006; Songer and Gotwals, 2012).

Finally, a third group seeks to analyze the quality of students' explanations. Results point to several challenges students face when they engage in elaborating and revising explanations, such as:

1. They tend to reduce the complexity of the information they are dealing with and try to frame the data in common-sense and simplified explanations (Zangori, Forbes and Schwarz, 2015; Andrade, Freire and Baptista, 2019);
2. They lack data to support the explanations (Songer and Gotwals, 2012; Seah, 2016);
3. They lack other basic components, in addition to data, to elaborate what is considered a good scientific explanation (Yeo and Gilbert, 2014);
4. They poorly associate important dimensions of a scientific explanation, such as its conceptual foundation, relations of causality, and levels of representation (Faria *et al*., 2014; Zangori, Forbes and Schwarz, 2015); and
5. They lack consistency when revising the explanations (Kang, Thompson and Windschitl, 2014).

Despite breakthroughs in the field, so far we do not know much about *how* students begin to construct explanations in science classes, considering their own ways to explain phenomena. Most of the studies offer greater visibility to issues that are challenging for students when they try to elaborate/revise explanations. In addition, few studies have associated multiple sources of data obtained from daily classroom activities (McCain, 2015). In this study, we seek to contribute to the literature by analyzing how a group of eighth-graders in Brazil[2] elaborated and revised explanations about a natural phenomenon. We analyzed the process in light of connections the very participants proposed during their everyday lives, using different sources of data.

THEORETICAL FRAMEWORK: EXPLANATIONS IN SCIENCE CLASSROOMS

One of the goals of science is to explain natural phenomena. However, constructing explanations is not restricted to scientific activity. It is, otherwise, a ubiquitous activity in human life (MacCain, 2015) because every day we try to find explanations for things we experience.

In science, explanations are designed in particular ways, and the Philosophy of Science offers relevant notes thereto. In 1948, Hempel and Oppenheim proposed that scientific explanations seek to describe particular phenomena starting from general laws (Hempel and Oppenheim, 1948). That is, in order to explain events of the natural world, scientists would look at natural laws capable of explaining them from logical results and well-established standards in nature. An alternative to the deductive model of explanation was the model proposed by Kitcher (1989), which argues that scientific explanations are constructed through the unification of seemingly unconnected phenomena. Thus, applying the same general laws to different phenomena in different contexts indicates a potential scientific explanation.

Another relevant aspect of these models is the role of causal relationships between the events investigated by science (Rodrigues and Pereira, 2018). In that sense, Salmon (1989) suggests that scientific explanations should include causal relationships as a feature that grants higher explanatory power. This type of relationship is identified when a system presents a new characteristic/behavior that would not occur if the relationship had not existed.

2 The classification we used is from the *Comparative Indicators of Education in the United States and Other G-20 Countries: 2015.* Retrieved from: https://nces.ed.gov/pubs2016/2016100/app_a3.asp.

In Science Education, there are several propositions about what can be considered an explanation in science classrooms (McCain, 2015; Andrade, Freire and Baptista, 2019). Nonetheless, both in research studies and in curriculum documents there is a shared sense that explanations in science classrooms are about a causal report that goes beyond the description of a phenomenon and seek to clarify how and why a phenomenon occurs (McCain, 2015; Tang, 2016).

Researchers have also proposed analytical models based on the identification of certain elements in the content of students' explanations, such as the presence of basic components (Andrade, Freire and Baptista, 2019); accuracy, abstraction, and complexity levels (Yeo and Gilbert, 2014); or an explanatory typology following canonical models of scientific explanations (Braaten and Windschitl, 2011). Therefore, those are more content-oriented analyses of the explanations.

However, from an analytical standpoint, they might deprive us from some relevant aspects of explanations as *construction processes.* Gee (2011) proposes that there are differences between content-oriented and structure-oriented discourse analysis. The latter refers to how certain discursive structures work and make sense when used in specific contexts (Gee, 2011). A few examples from the author are useful to this reflection. Gee (2011) provides two assertions: "1. Hornworms sure vary a lot in how well they grow. 2. Hornworm growth exhibits a significant amount of variation" (Gee, 2011, p. 9). Focusing on the structure of the discourse can help us understand issues that are beyond what the content is able to reveal. The structure of both assertions offers us examples of different ways of expressing things that are equivalent to different ways of doing and being in the world. Let's imagine a third assertion: "Hornworm growth sure exhibits a significant amount of variation" (Gee, 2011, p. 10). The strangeness we sense while reading it is a consequence of the mixing of structural elements that come from different contexts. On the one hand, we have an informal structure that we use in everyday life (assertion 1). On the other, we have an objective, non-emotional structure (assertion 2). Mixing them "breaks the rules" because the scientific voice incorporates an expression of excitement. This example emphasizes the discursive structure of an explanation-not only its content.

At school, when asked to scientifically explain something, students do not ignore those strategies. They explain in ways that do not necessarily fit into what we consider a scientific framework. Neglecting these strategies means giving up an important part of how students establish connections between their private and collective repertoires to what is being proposed in science classrooms. Therefore, participants' perspectives would have more visibility if our analyses considered *what* students say when proposing/revising explanations (content of the discourse) in light of *how* students speak in their contexts of insertion (structure of discourse).

In the same direction, based on Jaegwon Kim's ideas, this paper intends to expand the definition of explanation, along with the visibility of what students do when they start a collective effort to elaborate/revise explanations in science classrooms. According to Kim, explanations are sets of propositions providing information supported by dependency relationships between the *explanans* (the propositions comprising the explanation) and the *explanandum* (the phenomenon being explained)[3] (Kim, 1994, p. 68).

That definition allowed us to identify explanations that students provided without necessarily considering if they had elements such as causal relations, references to evidence, or other previously defined categorizations and typologies. As McCain (2015) argues, Kim's definition (Kim, 1994) allows for dependency relationships between the components of an explanation. Causal or deductive dependency relationships which are important in Science Education are types of relationship, but they are not the only ones to be considered. Therefore, other common types in students' daily lives are also key in the construction of an explanation in science classrooms. This was an important

3 The distinction between *explanans* and *explanandum* was originally proposed in a seminal work by Hempel and Oppenheim (1948).

proposition to map the explanations constructed in a classroom while valuing not only instructional expectations but also meanings shared by students.

Discursive interaction data and artifacts produced by students in a sequence of science lessons were used. This research was designed after defining a key event where the class constructed their propositions to explain the phenomenon in a written text. One student's text, Mariana's, was selected to map the processes of elaborating/revising explanations experienced by the class throughout different lessons. Elements of the text were investigated following these research questions:

1. *What resources available in the group's social context shaped the construction of the student's explanation?*
2. *How was the use of those resources articulated with the proposition/revision of the explanations in science classrooms?*

THEORETICAL AND METHODOLOGICAL APPROACH

ETHNOGRAPHY IN EDUCATION AS A LOGIC OF INQUIRY

This is a qualitative study supported by Educational Ethnography tools and assumptions (Green, Dixon and Zaharlic, 2005). From this theoretical and methodological viewpoint, understanding what was said/written in a classroom demands analyzing not only the content of words but also the interactions with the insertion context. This type of perspective is based on the Bakhtinian concept of discourse (Bakhtin, 1981), as something that is not restricted to the spoken/written word but as an action that reflects or refracts previous actions.

Each local community develops a language with unique characteristics, linking texts, contexts, and events in their everyday life (Bloome *et al*., 2008). From such links, modes of writing and speaking of science in a classroom are discursively constructed within those spaces (Kelly and Green, 2019). Ethnography in education seeks to understand these links from the propositions of *intertextuality* and *intercontextuality* (Bloome *et al*., 2008).

Bloome and Egan-Robertson (1993) define intertextuality as a juxtaposition of texts. They argue that texts include written, oral, pictoric, and electronic languages, as well as elements that may not be generally associated with texts (e.g., architecture, pictures, and tables). A word, a sentence, or another linguistic resource in a text is linked to one, two, or more texts that are related because they share the same referent; or because they belong to the same genre, the same environment; or because one text leads to another (Bloome *et al*., 2008). In a social group's everyday life, intertextual relationships are continually proposed, acknowledged, and confirmed/contested by its members.

From that knowledge of intertextuality, Floriani (1994) proposes the notion of intercontextuality. For her, the contexts and daily events of a group can be juxtaposed and evoked in interactions among members. Contexts, in this case, are the multiple layers of a group's social life, involving "historical (relating both to past and future events), multiple (including potentially contradictory and contesting contexts), at multiple levels, and interactive (contexts affect each other)" (Bloome *et al*., 2008, p. 37). In that sense, tasks, lessons, or specific events in a group's life are considered daily classroom life contexts. These texts and contexts are discursive resources available in the group's social sphere for constructing daily practices.

This paper analyzes the practice of elaborating and revising explanations in science classrooms with intent to map texts, contexts, and events that shaped their construction among eighth-graders in the Brazilian school system. These constructs are relevant for the research because they can be evidence of relationships that have social significance for participants in the group, thus granting visibility to how the students themselves take over practices proposed in science classrooms as resources to construct knowledge.

THE CLASS UNDER INVESTIGATION AND THE SCIENCE LESSONS

This study investigated two classes of middle schoolers in Southeast Brazil.[4] The research group followed those students in their final grades (2018–2019–2020–2021).

This paper is based on data from one of those groups when they were in eighth grade. At the time, the group consisted of 26 students, 13 boys and 13 girls, from diverse ethnicities and social and economic backgrounds. The group's teacher, Sandro,[5] majored in Science and is licensed to teach Biology; he has about 20 years of experience as a teacher. Sandro was trained in Science Education and holds a master and a doctorate degree in the field. The lessons analyzed in this study were carried out when the group was studying the human body, particularly content related to the nervous system (Chart 1).

The last five lessons on that subject were planned following guidelines for teaching science through investigation (Pedaste *et al*., 2015; Carneiro *et al*., 2020) (Figure 1). The instructional goals comprehended engaging students in the use of conceptual knowledge about the nervous system in a way that was linked to practices of the epistemic and social domain of science (Duschl, 2008). The activities comprehended the students' engagement in discussions about an investigative-character issue and in elaborating explanations to the phenomenon being studied, followed by analyses of a database about the phenomenon.

CONSTRUCTING AND ANALYZING DATA

Data was collected during active classroom observation of lessons (Spradley, 1980) in writing (in a field notebook), audio, and video recordings, as well as by collecting artifacts (Green, Dixon and Zaharlic, 2005). The analyses were performed in two levels: macroscopic and microscopic (Castanheira *et al*., 2001).

By using macroscopic representations of the classroom's daily routine, a Class Chart with general information about the science lessons throughout 2019 was designed, offering a wide perspective on habitual activities in the group. In the chart, the central topic of each lesson is identified along with the activities the teacher proposed, the approaches used, and interactional characteristics of the lessons. Subsequently, the data was segmented considering the research goals and the characteristics of the group investigated. From the Class Chart, we identified events where students tried to elaborate and/or revise explanations (Kim, 1994) in the classroom (Figure 2).

From this set of events, the five lessons about "phantom limb pain" which took place between June and July 2019 were the focus of this study. Those were the chosen lessons because this was the first time students were engaged in proposing explanations about science. Until then, the instructional context in science classes was based on the teacher presenting explanations to the group, and not on the students elaborating/analyzing explanations themselves.

This aspect of the group's history gave us evidence of the analytical potentials of the classes. According to Ethnography in Education, events that mark the beginning of certain daily practices have privileged analytical potential. These events enabled us to characterize the practices of proposing/revising explanations when they started to be negotiated among the participants. In this type of event, the way participants negotiate their routines, expectations, tasks, and roles becomes more visible to the observer (Collins and Green, 1992).

After this analytical decision, maps of events were built for each of the five lessons about phantom limb pain, describing students' actions and reactions while engaging in proposing/revising

4 According to the Brazilian education system, Basic Education (Educação Básica) comprehends nine levels called grades. Each level usually corresponds to one year of schooling. To learn more, visit https://nces.ed.gov/pubs2016/2016100/app_a3.asp.

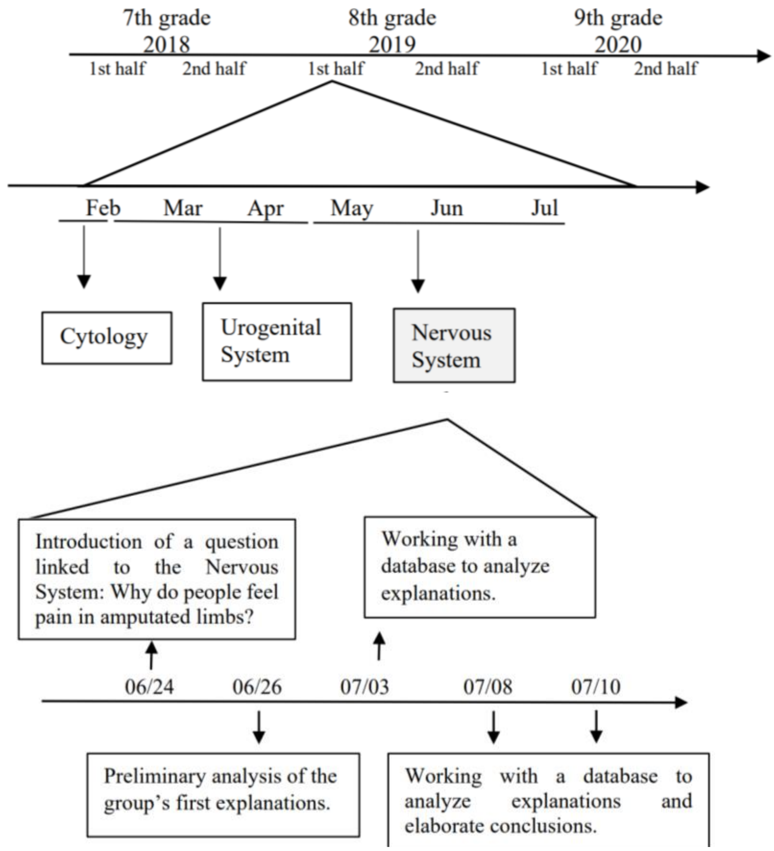
5 Pseudonyms were used to identify the teacher, the researchers, and the students. The project was approved by the Ethical Board of the competent institution, committed to the ethical principles of research involving human beings.

Chart 1 – Event 1.1.

Line	Speaker	Speech
1	Teacher	Why is it that she feels this ingrown toenail someone stepped onto↑
2	Bárbara	It's psychological
3	Teacher	It's psychological ↑
4	Bárbara	If she thinks there's a nail there *
5	Teacher	Ahn ↑
6	Bárbara	I think that *
7		If she thinks there's a nail there *
8		She's going to speak *
9		No *
10		There should be a nail there *
11		And then *
12		Someone steps on it *
13		I think it's already wired so that she knows someone stepped on it *
14		Even if she doesn't have a leg *
15		I don't know *
16		I think that *
17	Teacher	Is that so ↑
18	Students	XXXX *speak at the same time*
19	Teacher	Breno *
20		What do you think ↑
21	Breno	XXXX
22		I have an ingrown toenail * *he makes vertical gestures, with an open hand and spread fingers accompanying each word of the sentence*
23		XXXX
24		The toe hurts *
25		No *
26		She has an ingrown toenail * *expression of surprise*
27	Teacher	Let's hear this *
28		Jonas *
29	Jonas	Isn't the nervous tissue stretched like this ↑ *he makes a gesture as if he were showing a vertical line using his hands*
30	Teacher	The spinal cord *
31		Right ↑
32	Jonas	No *
33		The+ axon there *
34	Teacher	Hu+m *
35	Jonas	And *
36		Then *
37		The doctor must have cut it * *he makes a gesture of scissors cutting in the air*
38		Then a nerve was cut off but a few remained *
39		A nervous cell there * *he makes a gesture with his hands indicating a ball of wool*
40		Then it goes all the way up *
41		I don't know *
42	Teacher	It's another hypothesis *
43	Pierre	Teacher *
44		I know what it is *
45	Teacher	Hum *
46		Pierre *
47	Pierre	For the transmission of the nerve impulses *
48		There's that small space right ↑
49		His small space is greater *
50	Teacher	Look *
51		We already have a few hypotheses here *

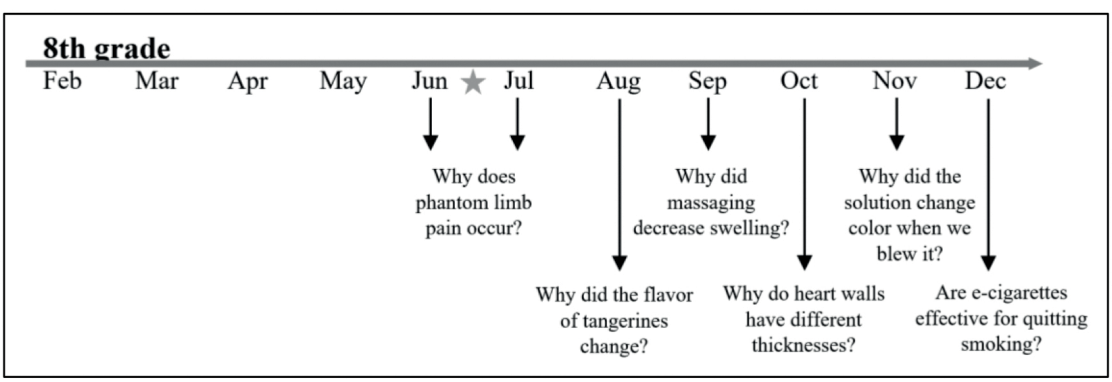
Symbols used in transcription: ↑ increase in intonation; * pause; *** long pause; ▼ low speech volume; + vowel lengthening, nonverbal behavior in italics; emphasis underlined word.
Source: created by the authors.

Figure 1 – Activities about pain in phantom limb in the context of the 1st half of 2019.



Source: created by the authors.

Figure 2 – Events where students' engagement in elaborating/revising explanations in science classrooms were identified.



Source: created by the authors.

explanations. This analytical process led to a new segmentation and a key element was defined as the door to microscopic analysis. That particular event was identified toward the end of the last lesson about phantom pain while the teacher asked the students to write a text explaining the phenomenon they had investigated. The text made by one of the students, Mariana, provided us with revealing elements of the group's discursive process to construct explanations.

The student's work had structural and content elements (Gee, 2011) that served as indices of other texts, events, and contexts of the group. Therefore, Mariana's text grounded these analyses, considering it guided the mapping of the group's routine. Intertextual and intercontextual relationships were mapped and used as evidence to support assertions about how the group elaborated and revised scientific explanations.

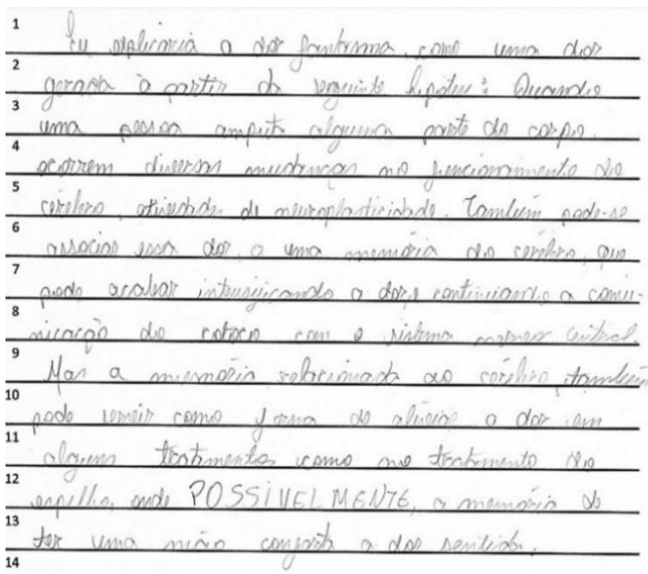
The events were analyzed through transcriptions of the interactions in message units, identifying the contextualization clues of the speech (Green and Wallat, 1981). We tried to describe non-verbal aspects of the discourses, such as intonation shifts, speaking speed, pauses, glances, gestures, etc. (Gumperz, 1982), thus valuing how the participants themselves assigned meanings to their discourses (Green and Wallat, 1981).

RESULTS AND ANALYSIS

MARIANA'S TEXT

At the end of the last lesson about pain in the phantom limb, each student wrote a response to the following question proposed by the teacher: How would you scientifically explain phantom pain to a patient who is going through this situation? Mariana wrote the following answer (Figure 3).

Figure 3 – Text 5.3 – Explanation elaborated by Mariana.


Eu explicaria a dor fantasma como uma dor gerada a partir da hipótese: Quando uma pessoa amputa alguma parte do corpo, ocorrem diversas mudanças no funcionamento do cérebro, atividade de neuroplasticidade. Também pode-se associar essa dor a uma memória do cérebro, que pode acabar intensificando a dor e continuando a comunicação do coto com o sistema nervoso central. Mas a memória relacionada ao cérebro também pode servir como forma de alívio a dor em alguns tratamentos como no tratamento do espelho, onde POSSIVELMENTE, a memória de ter uma mão conforta a dor sentida.

I would explain phantom pain using the hypothesis that it is a pain generated because, when a person has any part of their body amputated, several changes occur in the functioning of the brain, in neuroplasticity activity. This type of pain can also be associated with a memory in the brain, which may end up intensifying the pain and maintaining the communication between the stump and the central nervous system. But brain memory can also serve as a way to relieve pain in some treatments such as the mirror treatment, where, POSSIBLY, the memory of having a hand comforts the pain.

Source: created by the authors.

Right at the beginning, Mariana's text points out that the explanation for this phenomenon would come from a hypothesis that associates two possibilities: shifts in how the brain works and the memory it holds on to. The latter could act in such a way as to either intensify or relieve the pain. At the end of the text, she adds emphasis to the term *possivelmente* (possibly), writing it in capital letters. Considering the construction of this explanation as a social process, two aspects of the text guided the mapping of intertextual and intercontextual resources: structure and content.

The former is about presentation structure, using textual marks that would indicate uncertainty about the answer. The latter refers to the content of her explanation, which reflects the decisions made by Mariana when she selected which ideas would be the most adequate to explain the phenomenon.

WHAT RESOURCES AVAILABLE IN THE GROUP'S SOCIAL CONTEXT SHAPED THE CONSTRUCTION OF THE STUDENT'S EXPLANATION?

One of the resources that shaped the construction of Mariana's explanation was how the teacher led discussions in the classroom. During the lessons, since the first one, the teacher tried to make it clear that the answers to phantom limb pain should be understood as explanation propositions. Instead of presenting a straightforward answer to the question, Mariana chose to begin her explanation with a preamble: "*Eu explicaria a dor fantasma como uma dor gerada a partir da seguinte hipótese*" (I would explain phantom pain using the following hypothesis); and finish it by highlighting a certain degree of uncertainty: "*POSSIVELMENTE*" (POSSIBLY). This structure sheds light on how the group was proposing/revising scientific explanations.

In the first lesson, the teacher presented the phenomenon that would be investigated using a young YouTuber who had had her leg amputated but felt pain in an ingrown toenail of the amputated limb as an example (Chart 1).[6]

In this event, the teacher singled out a different form of relating to the answer to the question he had posed (L1). As was pointed out in the macroscopic analysis, this is the first event of the school year where the students were invited to propose explanatory hypotheses. While questioning "is that so?" (L17), Sandro demonstrated uncertainty when he reacted to the first hypothesis, elaborated by Bárbara. Subsequently, the teacher offered other students the chance to speak, which showed that there would be other propositions to be considered (L19-20, L27-28, L45-46). When he classified the students' answers as different hypotheses (L42, L51), the teacher expressed an expectation that explanations for the phenomenon should be understood as possibilities. This expectation was kept throughout lessons in future events. Still during the first lesson, while reading an introductory text about phantom pain, the teacher proposed there was an intercontextuality with event 1.1 (Chart 1).

The teacher evoked the event that had taken place at the beginning of the lesson, revising potential explanations delivered by the Chart 2. In addition to the relation between events, the teacher evoked

Chart 2 – Event 1.2.

Line	Speaker	Speech
1	Teacher	It says here *
2		That this phantom pain is a very controversial matter for science *
3		Either science cannot explain it effectively yet *
4		Or there are several explanations *
5		We've seen some of them in our classroom right ↑
6		Vinícius said *
7		For example *
8		Psychological *
9		Pierre suggested a problem in the synapse
10		Jonas suggested something *
11		A hypothesis *
12		Of the axons *
13		And science also has several hypotheses *
14		Now it's our turn to propose explanations *
15		Hypotheses *

Symbols used in transcription: ↑ increase in intonation; * pause.
Source: created by the authors.

6 Symbols used in the transcription: ↑ rising intonation; * pause; *** long pause; ▼ low volume of speech; + vowel elongation, *italics for non-verbal behavior*; word underlined for emphasis.

another context: the elaboration of explanations by science (L2-4). What took place in the classroom (L5) would be related to the scientific form of elaborating explanations (L13). After announcing that this would be the moment for the group to propose their explanations, the teacher split the group into six smaller ones and requested that each of them thought of three possible explanations.

In following events, they resumed these explanations as possibilities and uncertainties. In the fifth lesson, the group discussed the use of a database as possible evidence to assess the explanations. The teacher explicitly resumed the discussion about how to understand the hypotheses (Chart 3).

Chart 3 – Event 5.1.

Line	Speaker	Speech
1	Teacher	She (Nara) associated the first with the third *
2		But *
3		With- *
4	Nara	No
5		Of the first with the seventh piece of evidence *she raises the paper that was in her right hand*
6	Teacher	Yes *
7		But in that argument that she used
8		She brings up the argument that the hypothesis is a true statement
9		Is the hypothesis true ↑
10	Camila	XXXX
11	Nara	No *
12		It is doubtful *
13	Teacher	It is doubtful
14		So
15		Be very careful when you argue *

Symbols used in transcription: ↑ increase in intonation; * pause.
Source: created by the authors.

The teacher questioned the link that the student Nara had made between two hypotheses that were being discussed: the first and the third (L1). Actually, Nara was linking the first hypothesis with one piece of data from the database, the seventh piece of evidence (L4-5). However, at that moment the teacher had understood that the student was using one of the hypotheses to corroborate another hypothesis, which would not make any sense, because it would be like recognizing that one of the hypotheses being analyzed would be a piece of data (L8). Nara acknowledged that the hypothesis should not be considered a piece of data, but a doubt (L11, 12).

This event reassures the teacher's expectation in stressing out the conception of explanation that was at stake. The moment he realized a possible interpretation that would not meet this expectation, he paused the discussion to resume the idea that a hypothesis should not be understood as truth, but as something uncertain. In the previous lesson, the teacher had taken a similar action. However, his proposition was not clearly about how to consider an explanation, but about how the explanation would be constructed. The students were also discussing the use of a database as possible evidence to assess the explanations (Chart 4).

Chart 4 – Event 4.1.

Line	Speaker	Speech
1	Teacher	A significant number of groups *
2		Marked that this piece of evidence of neuromas *
3		It is a good explanation *
4		For the hypothesis that *
5		The central nervous system *
6		Continuous to send impulses to the distal end of the stump *
7		Why ↑
8	Mariana	Because the brain has not yet warned *
9		It understands that there's still a limb *
10	Tina	Because it *
11	Teacher	Tina! *he points to the student*
12	Tina	Because it's still wired to send *
13		To keep sending the nerve impulses to the place tha+t *
14		In this case *
15		There was a hand *
16		And there isn't *
17		A+nd *
18		The impulses cluster there *
19	Mariana	Yeah *
20	Tina	And it will lead to nowhere *
21	Teacher	Then *
22		It means *
23		It keeps sending *
24		But wouldn't that be a memory issue ↑
25	Student	Then it would be the four * *reference to the hypothesis that explains phantom pain originating from cerebral memory*
26	Teacher	If he already remembers he had *
27		It's not hypothesis four anymore ↑
28		I mean *
29		There was the memory from this limb *
30		It used to send the impulses and it keeps sending ↑
31		What do you think ↑
32		Because the second *
33		The third hypothesis is *
34		Phantom limb pain *
35		Occurs due to the continuity of the impulses *
36		Between the nervous system and the distal end of the stump *
37		So ↑
38		Do you think she has it ↑
39		You're telling me that *
40		That number three *
41		It has something to do with number four as well ↑
42		How does this thing work ↑
43	Tina	Yes *
44		Yes *
45	Teacher	Why ↑
46	Students	XXXX *Speak at the same time*
47	Teacher	Guys *
48		You have to pay close attention to this exercise *
49		Really close *
50		Because it will say what the phantom pain is *
51		OK ↑

Symbols used in transcription: ↑ increase in intonation; * pause; + vowel lengthening, nonverbal behavior in italics; emphasis underlined word.
Source: created by the authors.

This event started from questioning the link between a piece of data — *neuroma formation* — and one of the hypotheses which explained phantom pain as the result of the continuity of impulses between the brain and the amputated limb (L1-7). Mariana and Tina proposed a link that was closer to another hypothesis, which explained phantom pain originating from cerebral memory (L8-9, L12-19). The teacher made this connection clear (L21-24) and questioned the students about it (L26-42). Tina agreed with the teacher (L43-44). However, when the teacher asked Tina to justify her response (L45), several students began to try to answer (L46). At that moment, some students expressed that there would be a link between the two hypotheses, others considered there would not. Therefore, possible links between hypotheses were not yet consensus among students.

The teacher then responded highlighting the dynamic of analyzing and negotiating the hypotheses at stake (L47-51). By validating and/or ruling out hypotheses, considering the analysis of the database, the group would construct an explanation for the phenomenon. In this event, the teacher elucidated how the explanation should be elaborated, reaffirming that a scientific explanation is not a finished product nor is it merely a reference material. It is a negotiation of possible ways to explain in light of the data and by joint effort.

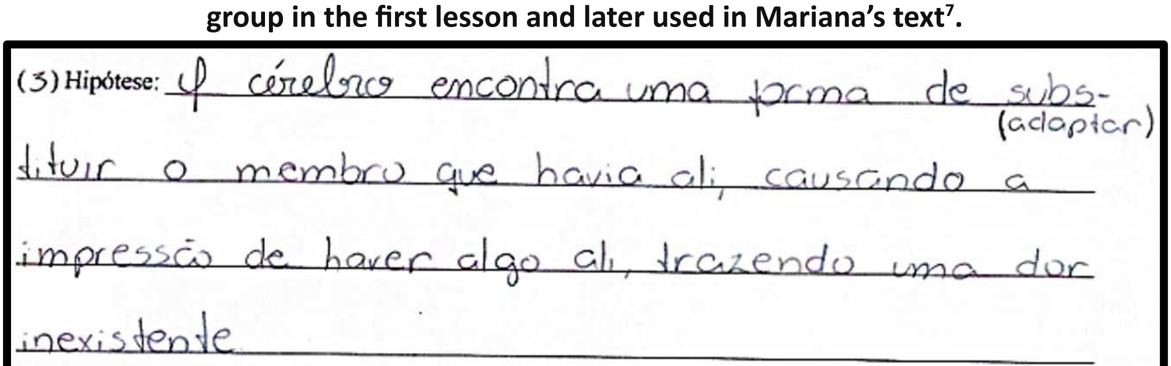
How Mariana began and finished her answer is in a way a frame that shaped the content of her explanation, reflecting the teacher's instructional expectations. Intertextual and intercontextual resources help us understand the content by evidencing the selection process of some explanations and the exclusion of others.

Among the five potential explanations the group was discussing, Mariana began by pointing out that, "*When a person has any part of their body amputated, several changes occur in the functioning of the brain, in neuroplasticity activity."*

Her uncertainty did not mean that she did not have a "better" answer. Neuroplasticity as the first choice for her explanation reflects a relative consensus constructed by the group throughout the lessons, which in turn results from linking a series of texts and events. This explanation had not been proposed by Mariana or her classmates (Bárbara, Vítor and Henrique) in the first lesson. Its origin could be mapped through the analysis of the set of texts written in the first lesson. This explanation had been mentioned by only one group (Guilherme, Lívia, Perseu and Luara). Throughout the activities, it became the most accepted one by the entire group (Figure 4).

This intertextual relation did not take place directly or explicitly. That is, Mariana was not in direct contact with these classmates to become aware of their text. Discussions in the whole class and in small groups mediated the relationship between these two texts.

Figure 4 – Text 1.1 – Hypothesis originally proposed by Guilherme, Lívia, Perseu and Luara's group in the first lesson and later used in Mariana's text[7].


(3) Hipótese: O cérebro encontra uma forma de subs- (adaptar) tituir o membro que havia ali, causando a impressão de haver algo ali, trazendo uma dor inexistente

Souce: database.

7 The brain finds a way to replace (adapt) the limb that was there, causing the impression that something is there, generating nonexistent pain.

Guilherme, Lívia, Perseu, and Luara's hypothesis was presented to the whole group only in the second lesson, along with other hypotheses that would be analyzed from then on. Up until that moment, there had not been any reference to the activity of neuroplasticity, a term used in Mariana's text. She added that term after becoming familiar with another text (Figure 5), which was introduced in the third lesson, when the small groups began to discuss the database about the phenomenon.

Figure 5 – Text 3.2 – Medical research no. 6.

Medical research no. 6 results

Research has pointed that when there is an imperfect or incomplete formation of a limb in the body, there are neuroplasticity activities in the brain.

Neuroplasticity activities are changes in the brain that involve the loss or appearance of nerve connections.

There is an extraordinary adaptation and reorganization capacity in the central nervous system. For instance, nerve fibers that control pressure or touch sensations might begin to control pain sensations, depending on the situation.

Source: Blasing B, Schack T, Brugger P. The functional architecture of the human body: assessing body representation by sorting body parts and activities. *Exp. Brain Res* 2010; 203:119–129.

Souce: database.

In this set of data, medical research no. 6 presented information about phenomena that generated neuroplasticity activities. The term then began to be used by the group as a synonym of the brain changes initially suggested in the first lesson in Guilherme, Lívia, Perseu and Luara's text.

This first hypothesis was the one with the least disagreement among the students during discussions with the whole group. Most of the groups, after analyzing the database, began to consider that brain changes would be the leading cause of phantom limb pain. The summary table that was elaborated in the last lesson, after the discussion with the whole group, gives us evidence of the consensus.

In this table, the teacher compiled the data from the analyses that each group made during the third lesson. After discussing with the class, the teacher compared each group's analyses to identify consensus and resolve dissents. The summary table (Figure 6) shows the number of each group that agreed to consider that a piece of data (columns) could be used as evidence to support a given hypothesis (rows).

In the fourth lesson, the group had initiated this discussion from what could be considered a consensus. For example, all the groups had considered that the first hypothesis was supported by piece of data no. 1 and that there were hypotheses (4 and 5) that all groups considered piece of data no. 1 could support. The summary table shows that the first hypothesis, which was mentioned in Mariana's answer, is the one that obtained greater consensus when the analyses of each group were compared.

Intercontextual relations between the fourth and fifth lessons help us understand how the process took place. In the fifth lesson, when the teacher revised the comparison of the analyses among the groups, he used the connection between piece of evidence no. 1 and hypothesis no. 1 as an example of a link that was consensual among the groups in the discussion of the previous lesson (Chart 5).

Figure 6 – Text 5.1 – Summary table of the whole group with the analysis per small group.

EVIDENCE / HYPOTHESIS	1	2	3	4	5	6	7	8	9	10
1. Changes in brain functioning	123 456	6		3	3	123 456	1,235 6	4		25
2. Psychosomatic origin	3	14		4	4			6	25	124 6
3. Nerve synapses continuity	2	3	24 56	56	6		5	1	13	13
4. Memory the brain holds on to		6	13	1		13		356	456	256
5. Nerves remaining			24 56	126	125		34		6	

Souce: database.

Chart 5 – Event 5.2.

Line	Speaker	Speech
1	Teacher	All groups *
2		Marked that piece of evidence no. 1 *
3		Was sound to the hypothesis no. 1 *
4		That says ***
5		What was hypothesis no. 1 ↑
6		Phantom limb pain *
7		Occurs due to a change in the brain’s functioning *
8		And what does piece of evidence no. 1 say ↑
9		It says this *
10		When you touch the face of an amputated person *
11		Who feels phantom pain *
12		This person feels the phantom limb *

Symbols used in transcription: ↑ increase in intonation; * pause.
Source: created by the authors.

The text containing Mariana’s answer shows the consensus confirmed by the teacher in the last lesson (L1). This can also be seen in the set of texts with her classmates’ answers. Most of the students mentioned, in their individual texts, that neuroplastic activities would explain the origin of phantom limb pain.

In addition to that hypothesis, another explanation was recurrent in the texts, as well as in Mariana’s: the memory the brain holds on to. For the student, in addition to the neuroplasticity, *“This type of pain can also be associated with a memory in the brain.”* A series of intertextual relations help us understand how such an explanation was proposed and negotiated throughout the events.

Initially, the propositions elaborated in groups in the first lesson formed a total of 18 hypotheses. In the second lesson, these hypotheses were put into discussion with the whole group.

Throughout this lesson, the group performed a collective reading of each hypothesis, which was pinned by the teacher on the whiteboard (Figure 7). The discussion started from the seemingly more consensual ones. Similar hypotheses were grouped into a wider category, which took place in most cases. In other cases, some hypotheses were considered inadequate, hence being discarded from the list pinned in the whiteboard. Thus, from the second lesson on, the group started to discuss a new set of five texts (Figure 7):

> 1. *Phantom limb pain occurs due to changes in the brain.*
> 2. *Phantom limb pain occurs due to psychosomatic issues.*
> 3. *Phantom limb pain occurs due to the continuity of nerve impulses (nervous synapses) between the central nervous system and the distal end of the stump.*
> 4. *Phantom limb pain occurs due to the memory the brain holds on to about what it was like when the limb was still there.*
> 5. *Phantom limb pain occurs due to the permanence of nerves that were cut at the distal end of the stump.*

Figure 7 – Text 2.1 – Set of hypotheses organized into five explanation propositions[8].

Souce: database.

In Mariana's text, the second hypothesis mentioned was that of the memory the brain holds on to, which corresponded to the fourth hypothesis of the list created in the second lesson. The idea of cerebral memory appeared in five of the six texts written by the small groups in the first lesson. Therefore, this proposition expressed a strong idea within the group, even before the process of analyzing the database or interpreting evidence. The mapping of events shows something the teacher said a few minutes before those texts were written (Chart 6).

The teacher used a student's report (L1-4, L6) to introduce a new piece of information (L7-14). He did not use the term "memory." However, when he mentioned that people who were born without a limb do not develop pain, he established a relation with the notion of memory. Thus, the teacher's text can constitute a resource available so that the small groups used this notion of memory, since the person would have to have a functional limb so that, by losing it, phantom pain occurred.

8 The numbers in the image indicate the place in the whiteboard where the teacher pinned each text, as well as the texts considered similar right beside them. Within the circle are the texts that were discarded due to being considered inadequate explanations.

Chart 6 – Event 1.3.

Line	Speaker	Speech
1	Tina	There was a TV show in which doctor XXXX
2		But she continued to feel pain *
3		It was like she really had her leg *
4		Then she had that sensation of the leg and all *
5	Teacher	What show is this ↑
6	Tina	Grey's Anatomy
7	Teacher	Guys *
8		Then *
9		You see *
10		This is common for people who suffer an amputation *
11		Not for people who are born with a limb reduction *
12		Then *
13		The person who is born without a limb is already
14		They don't feel this phantom pain *

Symbols used in transcription: ↑ increase in intonation; * pause; XXXX inaudible.
Source: created by the authors.

During analysis of the database, this hypothesis, which was already present in the initial ideas of most of the groups, grew stronger. During the third lesson, the students wrote an analytical table, in small groups, where they represented the possible relations between the data and hypotheses. As is the case with the first hypothesis, related to neuroplasticity, the proposition of cerebral memory was supported by more data in the interpretation of the small groups. The text with Mariana's group's analytical table supports this perception (Figure 8). This could also be seen in tables prepared by other groups.

Figure 8 – Text 3.4 – Table with the analysis of the hypotheses in small groups.

EVIDENCE HYPOTHESES	1	2	3	4	5	6	7	8	9	10
Phantom limb pain occurs due to changes in the brain.	X	X				X	X			
Phantom limb pain occurs due to psychosomatic issues.								X		X
Phantom limb pain occurs due to the continuity of nerve impulses between the central nervous system and the distal end of the stump.			X	X	X					
Phantom limb pain occurs due to the memory the brain holds on to about what it was like when the limb was still there.			X					X	X	X
Phantom limb pain occurs due to the permanence of nerves that were cut at the distal end of the stump.			X	X					X	

Souce: database.

In the fifth lesson, a new version of text 3.4 was written. This version was collectively constructed by the whole group, which is also evidence of the strength of the memory hypothesis (Figure 9). After the discussion among the small groups, with intent to construct consensuses with the class, the teacher facilitated a comparison between analyses. In addition, individual texts produced at the end of the fifth lesson highlight how strong this hypothesis is after analysis of the data. Fifteen out of 25 students mentioned in their texts that memory could be an explanation for the origin of phantom pain. Most of them mentioned both explanations — neuroplasticity and memory — in their arguments.

Figure 9 – Text 5.2 – Table with the analysis of the hypotheses by the whole group.

EVIDENCE / HYPOTHESES	1	2	3	4	5	6	7	8	9	10
Phantom limb pain occurs due to changes in the brain.	X					X	X	X		X
Phantom limb pain occurs due to psychosomatic issues.										X
Phantom limb pain occurs due to the continuity of nerve impulses between the central nervous system and the distal end of the stump.			X	X	X				X	
Phantom limb pain occurs due to the memory the brain holds on to about what it was like when the limb was still there.			X	X		X		X	X	X
Phantom limb pain occurs due to the permanence of nerves that were cut at the distal end of the stump.			X	X						

Souce: database.

Different from the neuroplasticity hypothesis, Mariana's second hypothesis was associated with other explanations. For her, memory could *"end up intensifying the pain and maintaining communication between the stump and the central nervous system. But the memory the brain holds on to can also serve as a way to relieve pain in treatments such as the mirror treatment, where POSSIBLY, the memory of having a hand comforts the pain"*. The student used different texts and contexts when she wrote this second part of her explanation.

Regarding the proposition of the continuity of impulses, only Mariana and two other students who were not in her group mentioned this link in their texts: Luara and Lara. This causal relation between memory and impulses was not observed in the class's social sphere nor in Mariana's group. The mapping of events discloses a possible relation between discussions during the fourth lesson (Event 4.1), when the whole group tried to come to a consensus around the use of a piece of data, medical research no. 3 (Figure 10).

The group considered that medical research no. 3 (Figure 10) might be a piece of data capable of supporting the proposition that pain is generated by the continuity of impulses from the central nervous system to the stump (see again Event 4.1, L1-6). The teacher provided evidence for this relationship and questioned the group (L7).

During the discussion, Mariana expressed that the brain *"understands that there's still a limb"* (L9), and this was reasserted by her classmate Tina when she mentioned that the brain "*is still wired to send"* (L12). Listening to those statements, the teacher's reaction was to question whether the third hypothesis — continuity of impulses — and the fourth hypothesis — cerebral memory — might be related to medical research no. 3. Even though the discussion did not reach a deep level, the students agreed with the teacher's proposition at the time (L25, L43-44). Thus, the teacher proposed a link between two texts

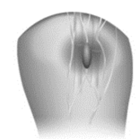
Figure 10 – Text 3.1 – Medical research no. 3 (Dickinson *et al.,* 2010).

Medical research no. 3 results

Studies have pointed to the formation of neuromas in the amputation area of people who report phantom pain.

Neuroma is a cluster of fibers formed by the nerves that were torn with the amputation.

In these neuromas, active sodium channels were identified, which generate *spontaneous discharges* and have an abnormal activity of *hyperexcitability*.



Representation of a neuroma that formed in a foot that had the fingers amputated.

Souce: database.

— the *third* and *fourth hypotheses* — and medical research no. 3, so that Mariana would interpret the hypothesis of the continuity of impulses as a consequence of cerebral memory. In her interpretation, the consequence of such a relationship would be an intensification of phantom pain.

Mariana also expressed that the memory the brain holds on to could generate another consequence: relieving pain through mirror therapy. In the third lesson, the group had received the database in which medical research no. 10 mentioned such therapy (Figure 11).

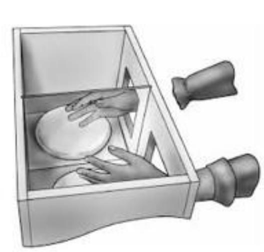
As the student said herself, *"the memory of having a hand comforts the pain".* The mapping of events reveals resources available for the student to construct that interpretation (Chart 7).

Figure 11 – Text 3.3 – Medical research no. 10 (Ramachandran and Altschuler, 2009).

Medical research no. 11 results

Patients submitted to the mirror therapy have obtained good results in phantom pain relief.

The patient watches the reflection of his intact limb in a mirror placed in such a way that the image seen corresponds to the amputated limb.



Souce: database.

Chart 7 – Event 5.3.

Line	Speaker	Speech
1	Nara	Let’s suppose *
2		If I memorized I had a hand *
3		But I don’t *
4		And I’m feeling pain *
5		Now at the mirror *
6	Pierre	What are you talking about ↑
7		Nara wait a minute *
8	Nara	Let me finish *
9		Now at the mirror *
10		I’m seeing and memorizing another thing *
11		Then *
12		In my head *
13		There’ll be a change there because+
14		I memorized it *
15	Student	I can’t believe I heard this Nara *
16	Teacher	Pierre said something that helped you Nara *
17		Pierre *
18	Pierre	Ok *
19		Here *
20		The person *
21		They look *
22		They have the sensation *
23		They see a+nd
24		Thinking that there’s a hand there+
25		They remember the sensation that they had when they had *
26		The memory of the sensation *
27	Mariana	Exactly *she claps her hands while speaking*
28	Teacher	Vinícius *
29	Vinícius	That’s what I was going to say *

Symbols used in transcription: ↑ increase in intonation; * pause; + vowel lengthening, nonverbal behavior in italics; emphasis underlined word.
Source: created by the authors.

This event took place at the end of the fifth lesson, a few minutes before Mariana wrote her answer individually. Nara proposed a possible relationship between mirror therapy and pain relief originating from cerebral memory (L1-5, L8-14). The same connection was reasserted by her group mate Pierre (L19-26). Mariana's reaction was emphatically agreeing with Nara and Pierre (L27), and this might explain her interpretation. Despite Mariana's emphatic agreement, the relationship between the use of mirror therapy and pain relief was not well accepted by the group. This interpretation came up in the final minutes of the discussion and was not fully developed. It was identified only in Nara's and Mariana's texts.

HOW WAS THE USE OF SUCH RESOURCES ARTICULATED TO THE PROPOSITION/ REVISION OF THE EXPLANATIONS IN SCIENCE LESSONS?

Intertextual and intercontextual resources provide elements for the interpretation of the proposition/revision of explanations in the investigated group, according to the representation in Figure 12. The arrows point to connections between texts on the right, contexts on the left, and events in the center, referring to the discursive construction of explanations in science lessons.

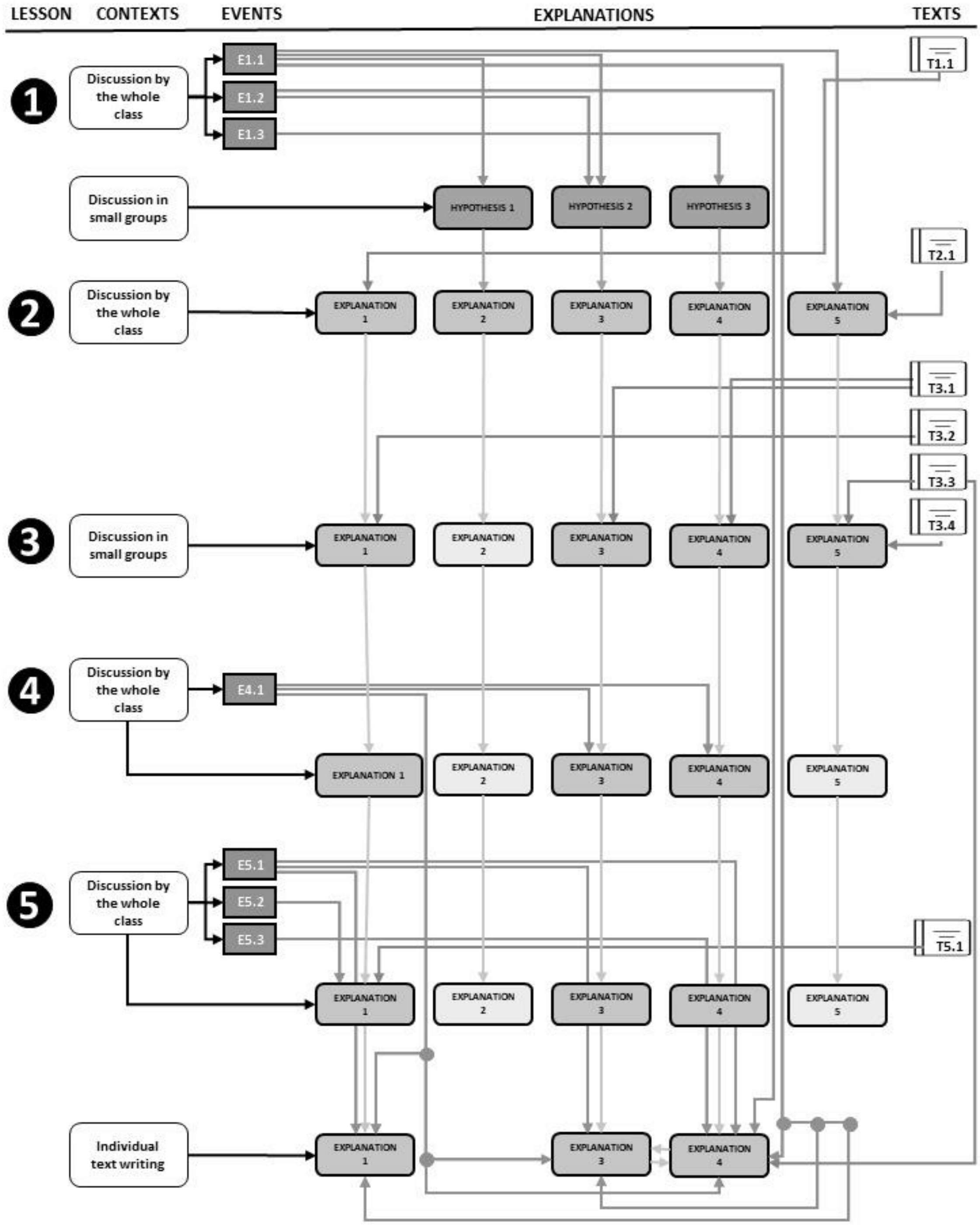
At first, Mariana had elaborated three possible explanations for phantom pain. The first stemmed from the group discussion with her classmates Bárbara, Vítor, and Henrique (instructional context of discussion in small groups in the first lesson, as represented in Figure 12). According to the group, the hypothesis that best explained the phenomenon was that phantom pain *"can be a psychosomatic disease when both the person thinks that the amputated limb is still there and the body releases substances that would act accordingly in the amputated limb".* That idea was linked to the first one that came up in the preliminary discussion with the whole group at the beginning of the first lesson, when Bárbara mentioned a possible psychological origin for the pain (E1.1, as represented in Figure 12). In this first lesson, Mariana's group also created two other explanations.

The second stated that *"neurons that were in 'contact' (close) with other neurons of the amputated limb were still performing synapses, and synapse creates the idea that the amputated limb is still there".* This proposition was also linked to event 1.1, when Pierre raised the possibility of pain being caused by synapse issues, which was reasserted by the teacher in event 1.2 (E1.1 and E1.2 in Figure 12).

Finally, in the third hypothesis, Mariana's group affirmed that *"the person's nervous system does not as yet understand that there is no longer a limb there and sends information as usual, functioning normally as if there was still a limb there".* This hypothesis had not yet come up in the discussion with the whole class at the beginning of the lesson. However, event 1.3 provides information related to this proposition. In that event, the teacher had mentioned that only people who had had the limb previously could feel phantom pain (E1.3 in Figure 12).

The instructional context of the discussion by the whole class, carried out in the second lesson, had consequences while revising the explanations. The class's propositions were organized into five big hypotheses, which became the focus of analysis from then on. Mariana's three initial explanations were altered during the process. Her first explanation became the class's second hypothesis, then enunciated as *"phantom limb pain occurs due to psychosomatic issues."* Her two other propositions became the third and fourth hypotheses, respectively, enunciated as: "*Phantom limb pain occurs due to the continuity of nerve impulses (nervous synapses) between the central nervous system and the distal end of the stump"* and *"pain in the phantom limb occurs due to the memory the brain holds on to about what it was like when the limb was still there."* What shaped these new explanations was the fusion of Mariana's group's initial explanations and other groups' initial explanations when their texts were similar.

Figure 12 – Intertextual and intercontextual relationships in explanations proposed and revised by Mariana.



Source: created by the authors.

One consequence of using these resources is that Mariana had to start thinking about two new possibilities as well, which she had not considered in the first lesson but were brought up by classmates from other groups. The first, *"phantom limb pain occurs due to changes in the brain"*, had been suggested by Guilherme, Lívia, Perseu, and Luara's group (T1.1 in Figure 12). And the fifth, *"phantom limb pain occurs due to the permanence of nerves that were cut at the distal end of the stump"*, which had been suggested by more than one group, was linked to the initial proposition by Jonas, who in the first lesson spoke about nerves that remained in the stump (E1.1 in Figure 12).

Using intertextual and intercontextual resources after the third class had a new consequence in proposing/revising explanations: the gradual strength some hypotheses gained to the detriment of others. The instructional context of discussion in small groups for the analysis of the database shaped this process. In Mariana's group, which had initially proposed a psychosomatic origin to phantom pain, an alteration was noticed. That explanation, represented in a lighter shade in Figure 12 after the third lesson, was then considered the weakest among the set of five possibilities.

Text 3.4 provides evidence for this consequence and indicates other relevant ones (T3.4 in Figure 12). First, two hypotheses came up as stronger for Mariana's group: the first explanation, which involved neuroplastic activities, started to be considered a good explanation; and the fourth explanation, that of cerebral memory, which had already been mentioned by Mariana in the first class and then became stronger. In addition, two other hypotheses were strong within the group: the continuity of nerve impulses (third explanation) and the nerves remaining in the stump (fifth explanation).

After the instructional context of discussion with the whole class, carried out in the fourth and fifth lessons, the fifth explanation was weaker (represented in a lighter shade after the fourth lesson in Figure 12). Therefore, the hypotheses which were more strongly supported by the database, after the group's analysis, were the first, third, and fourth ones. The continuous revision of propositions, either in small groups or by the whole class, was reflected in Mariana's writing in the last lesson. Mariana reflected the group's relative consensus when she used two central explanations: neuroplasticity (first hypothesis) and cerebral memory (fourth hypothesis). However, Mariana refracted from this consensus in some aspects, as was evidenced by events E4.1 and E5.3 in Figure 12.

CONCLUSIONS AND IMPLICATIONS

In this research study, we analyzed how eighth graders in a Brazilian middle school proposed and revised explanations for a given phenomenon in science lessons. Regarding our first research question, it was possible to conclude that:

1. The ways the teacher guided the group shaped an uncertainty in Mariana's explanation;
2. The instructional context — either in a small group or in the whole class — became a resource through which the group validated or discarded explanations; and
3. The links between texts, such as established by successive data analysis tables, supported revisions of the group's explanations.

As for the second question, it was possible to conclude that the resources Mariana used reflected and/or refracted the construction of the group's explanations. These associations indicate that:

1. This construction process reflected the instructional expectation of uncertainty involved in a scientific explanation;
2. Explanations became stronger or weaker throughout the events;
3. Students adopted propositions that they had not thought of at first; and
4. Data coming from different texts were interpreted to compose the written explanation.

This research contributes to the field of Science Education and to pedagogical practices, first by triggering an analytical shift, focusing on the quality of students' explanations for the construction process. We analyzed events where students began to use scientific models to explain phenomena, even though the canonical elements of a scientific explanation were not yet being used (McCain, 2015).

The use of Kim's (1994) definition for an explanation was important in this sense. In the macroscopic analysis, the possibilities of identifying explanations were widened, without the need to consider, *a priori*, the presence of elements such as causality, references to evidence, or typologies. Mariana's answer, which is the focus of our analyses, did not manifest the evidence discussed by the group to construct conclusions. Several data were analyzed by the group throughout the lessons, and she did not use them to defend her stance. In addition, if we think about coherence in her explanations, from a theoretical point of view, ideas like cerebral memory and continuity of impulses are not strong among scientists. Thus, if tools commonly used to analyze students' explanations were applied (Van Duzor, 2016; Yao and Guo, 2017), the research conclusion would likely be aimed at Mariana's difficulties while learning how to elaborate explanations.

In that sense, one of the key questions for discussions in the field is: Did this student learn science throughout these lessons? Analyses indicate that she did. First, the way she structured her answer gave us evidence that she was using a way of "speaking science" at school (Lemke, 1990), which can be understood as learning science.

Secondly, considering the content of her answer, the changes expressed in Mariana's propositions and the fact that she later accepted the neuroplasticity proposition are also evidence of her learning (Yeo and Gilbert, 2014). Mariana had not considered neuroplasticity, and it was the explanation that created less disagreement among her classmates. By using the idea presented by another group and analyzing it in light of the data under discussion, she decided it would be a good explanation to begin her text. Mariana borrowed an explanation that became strong in the group's social sphere. Another aspect in this same direction was discarding the explanation based on the psychosomatic origin of the disease. Even though it was the first explanation that the group came up with, and Mariana's group reasserted it, this hypothesis became weaker after they analyzed the database. Mariana took hold of this assessment, and consequently ignored it as a possibility when she wrote her answer.

Mariana also moved away from propositions shared by the group in other aspects. This indicates a necessary concern with students' singularities in a classroom. The texts and events mapped in this paper are due to Mariana's singular options, soaked into her group's social context. If we were to analyze each of the final answers of the students in the classroom, we would find several links with other texts, contexts, and events that each student established when writing their explanation.

Finally, this research has implications for pedagogical practices. One concerns a question that has been widely discussed in the field: What kind of instructional support is necessary so that students can learn to propose and revise scientific explanations? (Tang, 2016). The events and artifacts analyzed are indicatives of an answer. The analyses corroborate the results found by Gerard, Kidron and Linn (2019), which pointed to strategies of teachers seeking to help their students construct explanations, and were also relevant to the lessons analyzed in this paper. The authors point out the importance of the teacher clearly expressing the ideas that were progressively shared in class, clarifying the meanings that the students gave to their explanations, and suggesting changes to the explanations proposed. These strategies could be seen in analysis events (e.g. 1.3, 4.1, 5.1, 5.3) and in other events of the sequence of lessons that were not mentioned in this paper (Carneiro *et al*., 2021).

Another implication for pedagogical practice comes from the fact that the analyses involved a written explanation. Students' written explanations are an artifact that is universally available to teachers, even in classrooms where a traditional methodology is used (Seah, 2016). Research studies have analyzed how teachers try to assess these explanations. Summative assessment still prevails, and is related to the identification of explanations considered right or wrong (McCain, 2015).

Our research discusses such actions, enriching them because it approaches the written explanation from an interactional viewpoint. Even though the analyses are restricted to a single text, research was focused on the interactions among group participants. Analyzing a student's written assessment is a routine task for teachers. It is not always easy to assess this type of artifact beyond a summative perspective of learning. This study offers relevant notions so that teachers can understand individual artifacts from a processual perspective of assessment.

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