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Reading scientists in the high school classroom: peer and teacher mediation

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Abstract

The role of peer and teacher mediation in discussions about two original scientific texts in the final year of high school in Brazil is explored in this study. A text by James C Maxwell, deals with the characterisation of light as an electromagnetic phenomenon, and refers to the continuous manner of the distribution of energy by radiation in space. The other, by Ludwig Boltzmann, is about thermodynamics in its probabilistic conception and some of its consequences for the comprehension of the nature of heat. We analyse some of the students' interpretations using a version of discourse analysis, developed in Brazil following the French tradition of Michel Pêcheux. We highlight interactions that contribute to the reading of the texts and the mediations of both the teacher and peers that promote the establishment of relevant meanings about physics concepts. The appropriation of their statements about the content is observed in this communicative approach. We contribute to the investigation of physics teaching using strategies informed by a humane scientific and cultural educational perspective in high schools.

Keywords: original text, mediation, discourse analysis, science teaching, dialogical approach

1. Introduction

Science teachers in Brazil have been investigating approaches that promote the acquisition of scientific concepts while retaining the interest of students at all levels. This perspective values scientific education as a cultural and humanely directed endeavour that can also be enriching for those who will not use scientific knowledge directly in their professional lives.

The activity analysed here was part of a larger project, in which a teaching sequence was planned to introduce the initial ideas of quantum physics,

starting with the problems at the frontier of classical physics at the end of the 19th century [1]. This teaching sequence explored the reading of original scientific texts by high school students. Some of these texts are characterised by dialogue between the scientist and his peers.

We build on previous studies of teaching in Brazil, in which original texts of scientists were used, including Barth [2], Almeida and Sorpreso [3], Zanotello [4], and Batista *et al* [5]. In this study, the students read and discuss the texts of Maxwell [6] and Boltzmann [7]. We used discourse analysis (DA) to analyse the classroom discussions. Our research question is: how do the mediations of the researcher/teacher (R/T) and class peers contribute to students' meaning production?

2. Some cultural dimensions of the reading

Our presupposition is broader than an instrumental vision of scientific knowledge. This view understands physics, and other sciences, as work performed by people in cultural, historic, and social contexts, influenced by specific philosophies. The interaction of scientists with each other involves understandings of the activities—observation, experimentation, abstractions into concepts, laws, and theories and relationships—which overlap with technological developments. Scientific work, when examined in a historical context, provides an opportunity for the inclusion and recognition of numerous subjectivities. A good example is the discourse of Henri Poincaré, a scientist who has worked with physics and mathematics in his research. He argues that:

> …when it becomes rigorous, the science of mathematics assumes an artificial character which surprises everyone; it forgets its historical origins; look at it as if the questions can solve themselves, one does not see how or why they appeared. This shows us that logic is not enough, the science of the demonstration is not all of the science, and that intuition should preserve its role as a complement, one can almost say as a counterweight or antidote of logic [8].

We believe that reading favours the vision of the students. Almeida [9], after analysing the discourses of the students who read passages of an original text, verified that:

> …while they position themselves as readers, students whose attention is frequently distracted in physics classes, which use formal language that impedes understanding, are engaged [9].

3. Theoretical background and methodology

This study employs DA, in the French tradition of Michel Pêcheux. Language is not considered transparent or merely a support for thought; rather it is:

> …mediation necessary between mankind and the natural and social reality. This mediation, which is the discourse, becomes possible as well as the permanence, continuity, dislocation, the transformation of man, and the reality in which he lives [10].

In this perspective, discourse is understood as an effect of meaning between speakers. In the search to understand how it was formulated, the considerations of the immediate conditions and situations appropriate for the discourse, and questions that refer to the exteriority are of fundamental relevance. When we ask ourselves how such words and writings were formulated, we are referring to the production conditions of these words; the conditions in which '[…] history has its realness affected by the symbolical' [10].

The reading activities and mediated discussions were collected using audio recordings, later transcribed and supplemented with students' written answers. It is important to inform that this study was carried out in accordance with ethical principles and it had approval of university ethics committee (available at the full study [1], http://repositorio.unicamp.br/jspui/handle/REPOSIP/276900). All names used

are fictitious and participants consent was obtained. Any identifiable individuals are aware of intended publications.

The classroom activity incorporated the principles of Lopes *et al* [11] of fully revealing the tasks at the beginning and allowing sufficient time for reflection. The students' tendency to seek immediate answers was replaced with a quest for meaning, and the design of the activities facilitated several mediations. The texts of Maxwell and Boltzmann were selected to explore the fundamentals of electromagnetism and thermodynamics, respectively.

We divided the group in half, giving each one of the texts so that a general discussion could later be held. We aimed to provoke mediation between peers, in addition to interactions between the R/T and the whole group. The students were encouraged to read and discuss the texts in pairs and to formulate a written question based on the following instruction:

> *You have just finished reading a text by Boltzmann or Maxwell. Imagine that you are back in that time. Write a question to one of these scientists about something that you would like to clarify or know more about.*

4. Analysis of the discussions

Some of the students asked the R/T for help with understanding the texts and with formulating a question. They were challenged to be more investigative, or to elaborate on a question. Many students expressed doubts and even asked if the question that had been written was correct; a typical question arising from a framework in which work is 'right or wrong'. When it was evident that time was running out, the R/T reinforced the necessity for completion of the written question. This intervention was the catalyst for a dialogue:

> **Aline**: *It is difficult*.
> **R/T**: *Is it not possible that there is something in the text that you want to ask about?*
> **Aline** : *No, it is because that way… at first it seems difficult but then, after all, what we read is kind of logical…*
> **R/T**: *You can also ask a question to which you already know the answer… then it can be useful for us to use when discussing the text.*
> **Sarah**: *I wanted to ask if there was something in the medium…*
> **R/T**: *Possibly…*
> **Aline to Sarah**: *Is there something between the bodies? Yes, it is called the medium!* (they both laugh)
> **Sarah**: *Air!*
> **R/T**: *But that is an excellent question because he* (Maxwell) *talks about the different mediums between the bodies…*
> **Sarah to Aline**: *See?!*
> **Aline to Sarah:** *Wow… excellent question! Congrats!!!* (they both laugh)

Aline's initial comment conveyed her difficulty, and she responded to the questioning of the R/T with a hesitant negative. The mediation, referring to the text, resulted in the apprehension that it was no longer be difficult and had become *all logical*. The R/T directed her to something that she already knew.

This mediation was a catalyst for the generation of new thoughts about the activity of forming a question and encouraged her partner to contribute. The mediation specifically referred to the text, which *Aline* had tried to avoid. *Sarah* manifested an interest in 'the medium' in a general way. Although *Sarah's* interest had been piqued, her peer faced a subject in the text that had been read for the first time. Humour was employed to simulate an answer to the question, possibly obvious to both. Given that Maxwell points out the importance of the material medium for one of the theories, regarding the propagation of light energy, it is evident that this dialogue generated conceptual meaning.

The affirmation of the R/T sustained the meanings that the students produced and facilitated a link to a new concept. *Sarah*'s statement validated her question for her peer and signalled the relevance of her initial concern about the *medium. Aline* validated her elaboration, repeating the words of the R/T.

This example shows us the possible contribution of mediation in the classroom, to encourage the students to elaborate on the meanings they discover about physics concepts, stimulated by the reading of an original text. The approach of reading in science teaching, combined with mediation, promotes the possibility for new relationships with the knowledge. We understand that while those '…who do not feel secure in the use of mathematic language also do not feel able to learn physics, … the voice of scientists will have little space in a school environment' [9]. Mediation assists in overcoming this obstacle.

A discussion with the whole group was held at the end of the second lesson. With encouragement from the R/T, *Laís* raised a principal point about her understanding of Boltzmann's text:

> **R/T**: … *What are the principal topics you have learnt from the text? […] Let us begin with the thermodynamic text…*
> **Laís**: *It deals with the movement of the molecules of the bodies.*

First, the R/T encouraged *Laís* to continue explaining her notes and she was direct and synthetic in her response. Then the focus was adapted to direct the students to the examples in the text. *Rodrigo* intervened, specifying notions of physics, without making references to the principal theme: the existing differences in the transformation of heat in other types of energy.

> **R/T**: *Movement of the molecules of the bodies.*
> **Laís**: *That they have continuous movement.*
> **R/T**: *He gives many examples in the text, does not he? What does he use most as an example?*
> **Rodrigo**: *That kinetic energy and work are modified… they are modified into different types of energy.*

The R/T discussed the ideas raised by these two students, who had worked in a pair. He reiterated the inquiry with the whole group. Once again, *Rodrigo* and *Laís* were the protagonists:

> **R/T**: *He talks about energy modification… work and kinetic energy in other types, within this molecular movement. Was there a practical example that he gave, that caught your attention?*
> **Some students**: *The little balls… Yes, the balls…*
> **R/T**: *The mixed balls? What did you think about this example? …*
> **Rodrigo**: *A lot of little black and white balls that are moving and after a while, they stay together, and… mixed in some determined pattern…*
> **R/T**: *But they become mixed… They do not separate as they were in the beginning.*
> **Rodrigo**: *No…*
> **R/T**: *Is there any way that we can stir or mix them so that they return to how they were—separated?*
> **Laís**: *No, the probability of this happening is slight.*

In Boltzmann's text, many physical phenomena are used to illustrate his views about the distribution of thermal energy. He argues that the constituents of a body are determined by the probability of the system configuring itself into such a state. However, the only example, which is not reliant on microscopic concepts, was mentioned by some students, showing a distinction from the others explored by the scientist. It is possible that the meaning attributed by the students in the example of the little balls, was directly connected to something *concrete,* that can be accessed in the macroscopic world. Therefore, the examples left aside—those in which the scientist makes direct reference to the dynamics of the microscopic constituents of the bodies and the physical quantities implicated—possibly had no existence in the students' imaginations.

We noted that *Laís* made a unique contribution to the discussion, in which she justified

her answer by bonding the concept of probability to the distribution of the mixed colours of the little balls, even though directed, by the R/T, about the (im)possibility of being able to return to the state of colour separation that was observed at the beginning. On the contrary, after initially only being able to describe the example of the little balls to the other group, *Rodrigo* raised some questions, following synthesis of some of the ideas discussed previously by the R/T. In this sense, we understand that the student assumes a more investigative position and engages in improving his meaning production:

> **R/T**: *So, he compares the molecular movements with the mixed balls. White and Black. […] The other text mentions the molecular movement, of the gases, for example. So, he compares this to a mixture of white balls in a sack with black balls. Once they are mixed, they will continue to be mixed, never separating as they had been before…*
> **Rodrigo**: *But the balls have the same properties, only the colour is different.*
> **R/T**: *So, only the colour changes…*
> **Rodrigo**: *Like so… one hot body and a cold one has other different properties.*
> **R/T**: *OK, I understand… cold and hot bodies can be different, black, and white balls are the same, only the colour is different. So, how can we better describe this example? Or… do you think it is limited?*
> **Rodrigo**: *Yeah, I think that besides the temperature, it is the colours of the balls; there should be other properties that have an influence.*
> **R/T**: *Yes! I think that he tries to explore this in the text, does not he? He mentions the temperature and afterwards he talks about the energy too? So, we should discuss these two properties more…how these bodies, that have different temperatures and energies, get mixed in such a way that we can compare them with the case of the black and white balls.*

Rodrigo tries to make a direct association between the physical quantity and the property that he identifies as analogous in the comparison used by the scientist. He did not focus on the probabilistic principle proposed by the scientist, which is the centre of the analogy, and guides not only the configuration of colour distribution when mixed, but also the distribution of molecular velocities when a hot gas mixes with a cold one. However, dealing with the impossibility of such a direct association being valid, the student recognised that other properties influence the phenomena. Even without naming them, his discourse is marked by the possibility of a deeper understanding of the other properties, and the establishment of relations between them, which might explain the distribution of heat between the molecules. We can also discern within this dialogue the movement between authoritative and dialogic discourse by the R/T that Scott *et al* [12] describe. In their perspective, shifts like these create support for meaningful learning in communicative approaches, as evidenced by *Rodrigo*'s reflection.

5. Some considerations

The activity of reading original texts of scientists at school creates possibilities for the teaching of sciences that meet what Sodré [13] calls the necessity for pluralism of knowledge at school. It allows for the construction of aspects of reality in conjunction with the 'life story of each subject'.

We have shown that the mediation of dialogue between pairs of students, which was valued by the R/T, promoted the possibility for the articulation of students' questions about the readings. We explored the findings of Smith *et al* [14] that peer discussion enhances conceptual understanding of questions. We also demonstrated that the students' doubts can be allayed by discussing their point of view with the group and considering the main topics of the texts. This supports the view of Rivard and Straw [15] regarding the importance of talk when learning science. Talking plays a decisive role in sharing, clarifying, and

distributing knowledge among peers. The open discussions facilitated a deepening of meanings for some students. They went beyond descriptive bounds, with direct references to the topics of the texts they read, to explore explicative bounds. Our results indicate that the promotion of suitable conditions, and the provision of appropriate mediation, made it possible for the students to establish their meanings about physics, by appropriating their discourses about the content.

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References

[1] Pagliarini C R 2016 Readings from scientists of the beginning of quantum physics at secondary education: borders with classical physics Thesis (Doctorate in Science Teaching) 'Gleb Wataghin' Institute of Physics, University of Campinas, UNICAMP (http://repositorio.unicamp.br/jspui/handle/REPOSIP/276900)

[2] Barth M 2000 Electromagnetic induction rediscovered using original texts *Sci. Educ.* **9** 375–87

[3] Almeida M J P M and Sorpreso T P 2011 Analytical device for reading comprehension of different kinds of texts: examples about Physics *Pro-Posições* **22** 83–95

[4] Zanotello M 2011 The reading of original texts of scientists by students in a university course *Ciênc. Educ.* **17** 987–1013

[5] Batista G L F, Drummond J M H F and Freitas D B 2015 Primary sources in Physics teaching: considerations and examples of proposals *Cad. Bras. Ensino Fís.* **32** 663–702

[6] Maxwell J C 1954 *A Treatise on Electricity and Magnetism* vol 2 (New York: Dover Publications)

[7] Boltzmann L 2004 A segunda lei da teoria mecânica do calor *Escritos populares de Ludwig Boltzmann* ed A A P Videira (São Leopoldo: Editora Unisinos) pp 25–49

[8] Poincaré H 1995 *O valor da ciência* (Rio de Janeiro: Contraponto)

[9] Almeida M J P M 2004 *Discursos da Ciência e da Escola: ideologia e leituras possíveis* (Campinas: Mercado de Letras)

[10] Orlandi E P 2012 *Análise de Discurso: princípios e procedimentos* (Campinas: Pontes)

[11] Lopes B J *et al* 2008 Mediation of student learning: dimensions and evidence in science teaching *Probl. Educ. 21st Century* **9** 42–52

[12] Scott P H, Mortimer E F and Aguiar O G 2006 The tension between authoritative and dialogic discourse: a fundamental characteristic of meaning making interactions in high school science lessons *Sci. Educ.* **90** 605–31

[13] Sodré M 2012 Cultura e Educação *Reinventando a Educação: diversidade, descolonização e redes* (Petrópolis: Vozes) pp 15–72

[14] Smith M K, Wood W B, Adams W K, Wieman C, Knight J K, Guild N and Su T T 2009 Why peer discussion improves student performance on in-class concept questions *Science* **323** 122–4

[15] Rivard L P and Straw S B 2000 The effect of talk and writing on learning science: an exploratory study *Sci. Educ.* **84** 566–93

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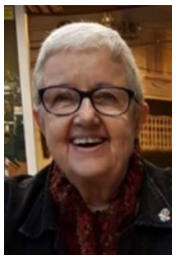

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