Research Article

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An analysis from teaching interventions focused on levels of conceptualization

Abstract

In this article, the didactic interventions of a future physics teacher are analyzed during the joint construction, with the group of students, of school scientific explanations of everyday phenomena in a secondary education classroom. The work aims to contribute to an under-researched territory, related to how teachers guide the construction of explanations in science classrooms. A case study focused on qualitative methodology was used, using thematic content analysis. Transcripts, class diaries and working sessions between residents and teachers were analyzed. An initial category system was built that was expanded inductively. A typology of discursive strategies used by the future teacher was developed, which includes strategies to promote conceptualization at different levels of representation of matter and meta-explanatory strategies to explicate aspects of the structure of explanations.

Keywords: teacher discourse, teacher training, discursive strategies, science teaching.

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Introduction

Discourse in the science classroom plays an important role in student learning. Previous research has investigated how Physics teachers use a variety of generic discourse strategies to foster classroom interaction and school content mastery.[1-3] However, there has been relatively little research used on how teachers' discourse can. Convey the construction of discursive genres, such as scientific explanation. The difficulties concerning teaching practices of scientific explanations, recovered from different studies, are related to several didactic dimensions. On the one hand, those associated with the lack of a clear conceptual delimitation in terms of the content and function of the explanations.[4] On the other hand, the elaboration of school scientific explanations is a practice closely related to writing practices.[5,6] Helping students understand scientific language remains a challenge for teachers. In order to write their explanations, students need to understand the scientific language employed to express concepts.

In this context, the teacher's didactic mediation during the construction of scientific explanations in the science classroom becomes relevant**.** Cognitive scaffolding has been used to improve the quality of explanations, such as the usage of indications to highlight key principles or asking students to explain the writing process based on questions.[4] Other scaffolding devices to support students during the construction of school scientific explanations included: writing heuristics,[4,7-9] explanation guides, explanation frameworks, integration frameworks,[10-12] and written scaffolds.[13,14] In this work we intend to contribute to analyze how future physics teachers guide students in the construction of school scientific explanations of everyday phenomena during discursive interactions with the group of students at high school level, Argentina. To do this, we resort to conceptualization levels[15] used by the future teachers during their discursive interactions, defined in terms of the levels of conceptualization. In this context, we intend to contribute to research on how teachers convey the construction of explanations in science classrooms in a scarcely investigated context, from an unexplored perspective in research.

Initial teacher training

Studies on the nature of social practices agree that "social practice" has a strong component of uncertainty and openness, mediated by reflective processes of interpretation of the participants and regulated by ethical standards, which can be expressed through a deliberative and dialogic dynamics of comprehension.[16] Edelstein and Coria[17] suggest talking about "teacher practice" rather than ''teaching practice", as a way of attending to what happens in the classroom and what happens in the social context as well. Teaching practice, like any social practice, is complex.[18] This conceptualization of teaching practice is part of the model or interpretative perspective of practice.[19-23]

We consider initial teacher training as a stage during which an intentional, systematic and organized educational practice is developed, aimed at preparing future teachers to perform their role. For this, during this process, the appropriation of theoretical and instrumental knowledge that enables them to exercise their professional practice is promoted.[24] In this training context, Professional Practices constitute a coherent and interdependent entity within the teacher training curriculum; they imply the immersion of the intern in institutionalized actions inside and outside the university environment, produced in a variety of settings in which the intern observes, intervenes, reflects, reconstructs and values realities in their complexity with the intention of building his own identity as a teacher.

The explanation of phenomena in the science classroom

The construction of explanations is a distinctive practice in science classrooms for a multitude of reasons. Research on explanations in science classrooms indicates that students who participate in the explanation change or improve their image of science and their understanding of the nature of science.[25-27] The active participation in the elaboration of scientific explanations in the science classroom contributes to build an image of scientific practices free from stereotypes, emphasizing the construction of arguments or explanations that include the weight of evidence, the interpretation of the text and the assessment of claims.[28] In addition, the construction of explanations can improve students' understanding of scientific content,[28] as long as this understanding would manifest in the ability to explain phenomena.[29] Emphasizing the importance of explanation in science classrooms, Osborne and Patterson[30] (p. 14) argue that providing explanations is the bread and butter of the science teacher's existence.

We characterize a scientific explanation as a narrative based on the articulation of theoretical knowledge and the interpretation of empirical facts, built through reasoning with the aim of making sense of a specific phenomenon. We differentiate between the conceptual structure and syntactic structure belonging to the content of an explanation. This differentiation, which recovers the perspective of Yeo,[31] allows, on the one hand, to recognize the importance of the elements common to all school scientific explanations -structure- and, on the other hand, to make the underlying reasoning -content- explicit. The consideration of this last dimension -content- is aligned with the warning opportunely formulated by Driver, Leach and Millar,[32] and recovered more recently in different investigations on this topic,[33] related to the fact that explanations based on the nomological-deductive model do not promote either critical reasoning or deep conceptual understanding. The reason that the authors provide on this matter is that in order to decide if a discourse is explanatory, it is also necessary to make explicit the association between the elements invoked to explain the phenomenon.

For the reading of the content of scientific explanations, we consider Taber's[15] proposal on levels of conceptualization. Taber[15] proposes that conceptualization in physics and chemistry is done at two levels: a macroscopic level (which includes terms such as 'substance', ́force', 'physical change', for example) and another level of conceptualization -submicroscopic level- (including terms such as ́electron', 'atom ́, among others). Following Taber[15] and other authors,[33,34] we consider that the observed phenomena are re-conceptualized not only at the macroscopic level but also in therms of theoretical models of the structure of the matter at the submicroscopic level. To represent the concepts of these different levels, physicists and chemists use formalisms: symbols, formulas, pictures of particles, molecular models, pictures of apparatus, etc. Taber[15] argued that the macroscopic level has a high conceptual demand for students because it supposes an abstraction of the phenomena. In addition, he emphasized that learning chemistry or physics involves conceptualizing phenomena at macroscopic and submicroscopic levels, called 'conceptualization levels'.[15] In the research that contextualizes this work, the future physics teachers, during their residency, worked with these levels of conceptualization during planning and in the classroom with the students. In particular, they thought and developed their teaching practices along with the construction of scientific explanations of everyday phenomena centered on the use of these levels. In this sense, the categories elaborated during the investigation -presented in this work- refer to this work and were formulated in terms of conceptualization levels.

Methodology

The research was developed from a qualitative approach. It is a type of interpretive research centered on the conversational content analysis technique.[35] The units corresponding to different cases[36] defined by the discursive exchanges between future physics teachers and groups of students at educational institutions of high school level in the Province of Buenos Aires, Argentina, during the instance of their teaching residencies. An in-depth case study focused on the theme 'gases' is proposed, prescribed in the curricular proposal of the Province of Buenos Aires. The didactic sequences developed by the future teachers -or interns- were contextualized in the physicochemical school subject, belonging to the second year of high school education, with students aged 14-15. The choice of the theme was intentional, since it allows work with different levels of the representation of matter, according to the didactic orientations of the curricular design for the physicochemical subject in the second year of high school (Province of Buenos Aires). In this paper we present the results of the content analysis corresponding to instances of exchanges between residents and a group of students during the joint construction of school scientific explanations. The class diaries prepared after each intervention, prepared by the interns, the transcripts of the classes and the instances of shared work between residents and teachers of the residence between the classes constituted the textual material for the analysis. From the approaches proposed by some authors for content analysis, the narrative approach of qualitative methodology was adopted, which analyzes the content of the discourse and is based on the postulates of the critical school, postmodernism and constructivism. For the analysis of textual data we used a content analysis that combines aspects of the directed and conventional approaches.[36] In the analysis process, an initial system of categories was elaborated, followed by an inductive procedure during which new categories were elaborated and the initial proposals were revised.[37]

For the general process of qualitative data analysis, characterized by its cyclical sequence, the model described by Saldaña[38] was recovered, focused on the instances of: data reduction/condensation; data visualization; drawing conclusions and verification/validation of conclusions. For the collection and recording of the information, different sources were used: video and audio recordings of the classes, note-taking during the classroom observation, and recording of instances of instances of socialization in the format of seminars conducted during the teaching residency.

'Data' is understood as a raw material from which the researcher must carry out the opportune operations that lead him to structure the set of information into a coherent and meaningful whole.[39] The data used in this research are textual. They correspond to verbatim transcripts of the classes and peer exchange sessions, interviews and class diaries as an intrapersonal narrative prepared by the resident.[40,41] While operations on the data are carried out maintaining its textual nature, this does not represent an obstacle for qualitative research to resort to the transformation of textual data into numerical data for its quantitative treatment.[38] Numerous statistical packages are used in qualitative research.[42-44] In this research we use NVIVO, a software created by Qualitative Solutions and Research Pty. Ltd from Melbourne, Australia. It is a widely used tool in qualitative research.[45,46] For the present work, the NVIVO software facilitated the performance of different activities during the research process: the division of texts into units of meaning (textual units); organization of the coding system (relocation and grouping of nodes) the assignment of codes and metacodes, the count of coded text units; establishing hierarchical relationships between categories; in the reading and codification of documents, the modification of the systems of categories; annotations; in the examination and investigation of documents; the recovery of texts from the coding carried out or from words of interest; the construction of textual matrices; the establishment of relationships between codes or the verification of qualitative hypotheses. For data visualization, word trees, word clouds, framework matrices, and coding matrices were used. For the purposes of this work, we consider that the system of categories built during the investigation are the results to be presented. In the following section, we refer to this system in context.

Results

With regard to the process of category construction during the research, during the period of the residency practices, the interns become internalized in the didactic perspective of the curricular proposal from the levels of representation of matter. These levels offer a frame of reference for work during the pre-active, active and post-active instances.[47] In addition, during the work on the matter, the resident participated in the joint construction of categories for the didactic analysis of the interventions considering these levels of representation. This conceptual system provided a group of initial categories (deductive stage of the research) defined as: conceptualization at each level, recognition of levels, and transition between levels. During the research, the coding process was mainly inductive. In an open coding stage[48] we redefine some of the a priori categories and create new categories. During the coding process we verified that certain codes could be regrouped or divided into others; that certain categories could be named differently or that they should be eliminated. Microscopic analysis during open coding was performed line by line.[49]

The coding process included instances of open coding and axial coding.[48] Various modes of open coding were performed –by paragraph, by document- although, and specially, it was developed through the process of microanalysis, using the labeling technique to code segments of text related to the same topic.[49] During this coding process, categories and subcategories emerged, defined and redefined in axial coding. This process allowed for the grouping of excerpts from class transcripts, instances of peer exchanges, and class diaries developed during open coding. These excerpts were later associated to categories, according to their characteristics and properties.

The categories corresponding to the "*conceptualization at each level of representation of matter*" include those discursive interventions made by the resident through which the recognition of a privileged level of representation of matter during interactions is promoted. These relationships were constructed during discursive exchanges between residents and groups of students, in processes of meaning negotiations that define thematic patterns legitimizing the discourses circulating in the classrooms.[50]

The categories associated with "*recognition of the level of representation of matter*" include those interventions carried out by the resident through which the recognition of a privileged level of matter representation during the interactions is promoted. Such recognition takes place differentially depending on the level of representation considered. The discursive interventions of residents show specificity according to the level of representation of matter in which the resident-student discursive interactions are situated. Didactic work with scientific explanations requires the simultaneous use of levels of representation. The practitioners developed discursive actions focused on the transition between levels of representation of matter, intended to guide the students in the construction of school scientific explanations. In this context, the discursive actions intended to promote the transition between levels on the discursive plane are registered, reduced in the analysis that we carry out to the strategy called *"guiding the construction of relationships between terms of different levels"*. In addition, during the didactic work between levels of representation, the residents guided the students in the transition, explaining the level in which they are working or in which they should work. The category we call *"Setting the level for discursive exchange"* refers to resident interventions in which she makes explicit the level of representation that should be worked on.

Another emerging category during the inductive stage of the analysis groups the resident's discursive interventions aimed at making explicit some aspects related to the *structure of school scientific explanations.* They belong to discursive interventions tending to make explicit the sequence of levels present in an explanation or during its construction, in the case of a joint construction ("[…] Yes? Well, what we are going to do is try to explain this experience, right? Do you remember the structure of the explanation that we had to follow?" line 214, Class 1); Discursive interventions with the aim of making explicit which entities must be present in an explanation ("Well, the first thing I have to consider before starting an explanation are the concepts that are involved in the phenomenon", line 216, Class 1) and discursive interventions tending to make explicit the presence of relationships between concepts ("The idea is that we control the structure of the explanation and the macro and micro concepts present here, to see if the explanation is correct, if it contains everything necessary, and then we will see the relationships between concepts", line 435, Class 1). While these interventions consider the explanatory text as an object of reflection, we group them in the category called "meta-explanatory discursive strategies". The category called "guide in the recognition of the sequence of levels-structure', also inferred during the inductive instance of the analysis, includes those discursive interventions of the resident tending to guide the construction or sharing of the narrative resorting to the criteria that structure the explanation (sequence of levels, concepts according to levels) and that the practitioners present to the students as clues to guide the explanation. The discursive interventions that exemplify this category were used by practitioners to organize the construction of statements in the explanatory text. In this sense, they differ from those that explain aspects related to the structure of school scientific explanations and that the resident uses as an indication of a more general nature to refer to the structure of the explanation and affect the explanation as a whole. The discursive strategies that exemplify the "meta-explanation" node correspond to those interventions where the existence of an explanatory structure is made explicit. Those that exemplify the node "Guide in the recognition of the sequence of levels-structure' include those that guide students in the recognition of the elements of the explanatory structure.

Finally, we differentiate, according to their hierarchies given by the level of inclusion, between first-order and second-order or level categories. Some of those described in this section delimit the set of first-level categories (conceptualization at the macroscopic level; conceptualization at the submicroscopic level; setting the level for discursive exchange; centered on the phenomenon; guiding the construction of relationships between terms of different levels; meta-explanatory). Some of the categories corresponding to this level come from the inductive stage. For some of the categories at this level we identify different modalities. For example, to channel the conceptualization at the level of macroscopic representation, in their discursive interventions, the practitioners promote the recognition of concepts typical of this level and make explicit the relationship between variables, among others. Figure 1 presents the matrix of frameworks where each of the categories is exemplified from the coded excerpts of the transcripts.

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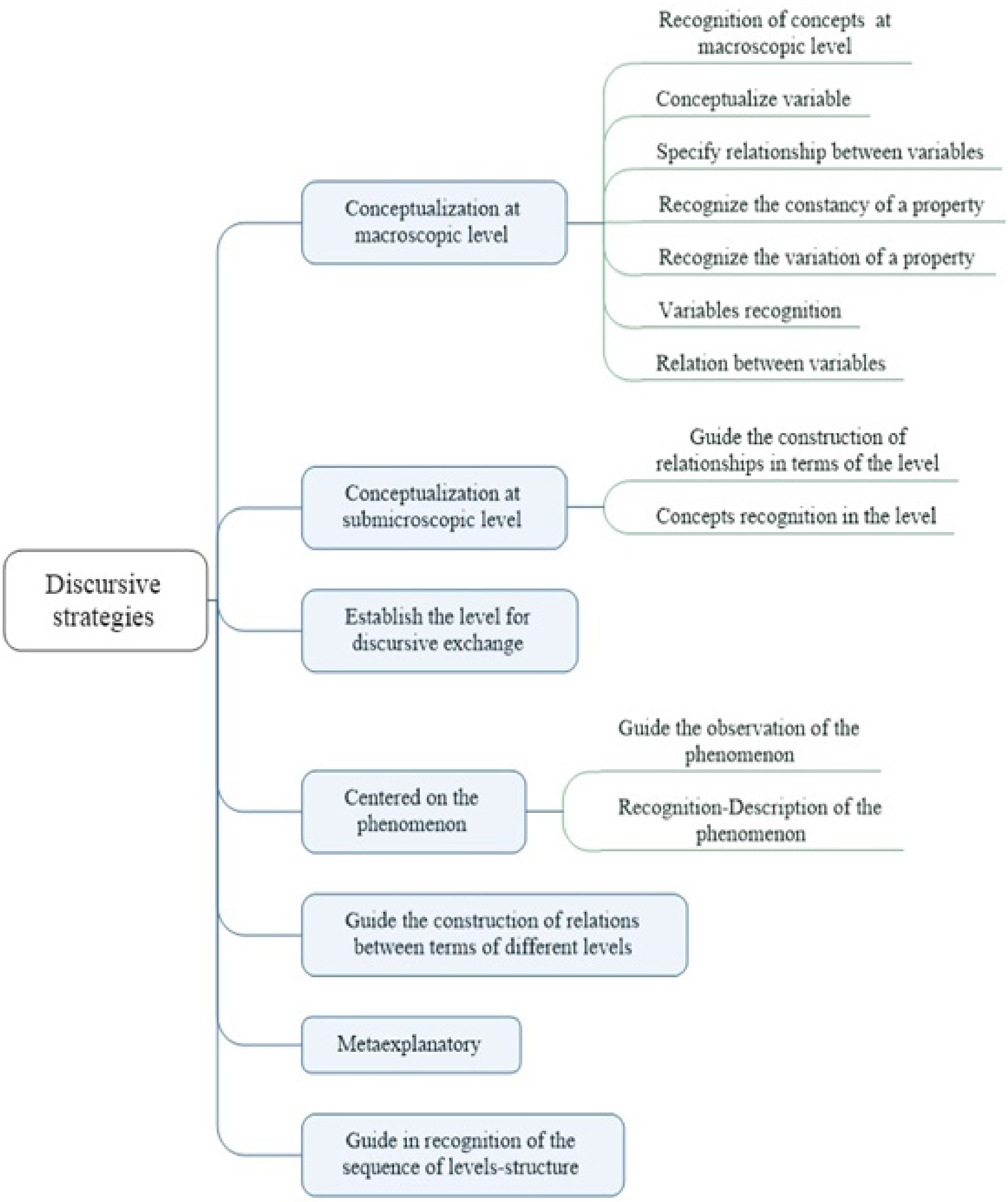

Figure 1 Matrix of frameworks where each of the categories is exemplified from the coded excerpts of the transcripts.

Final considerations

Learning to explain in the science classroom requires teaching interventions that mediate in its construction. The efforts of teaching interventions are usually directed at teaching the semantic relationships present in the model; however, they are minor —or non-existent- in terms of teaching how to explain. If learning science involves learning to speak science,[51] then school learning in physics should not disassociate knowledge about the subject from the domain of scientific language genres. The discursive interactions in a physics class combine different types of texts, different linguistic structures that must be taught and learned.

In this paper we present modalities of discursive interventions used by future physics teachers at the interpsychological level to guide the teaching of explanations in the context of teacher training. The didactic work was developed around the levels of conceptualization that guided the discursive interventions of the practitioners and, in addition, provided the interpretative framework for the construction of the system of categories for analysis.

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This study aims to contribute to research on teaching practices focused on the construction of school scientific explanations from different places. On the one hand, since their enrollment in initial teacher training, considering that the different investigations in this line are contextualized in in-service teachers, this contribution can be placed in relation to the one discussed below.

Another contribution of this study refers to the fact that in this work we do not analyze "spontaneous" teaching practices based on scientific explanations, but rather explicitly stated in teaching intentions and plans for their implementation in the science classroom. This contribution is part of the need for reflective training that allows teachers to think about their discursive interventions aimed at promoting learning of school scientific explanations of everyday phenomena. This importance is related to the claim of Braaten and Windschitl,[52] referring to the fact that, in order for teachers to encourage students to elaborate explanations, it is necessary to provide guidance on the nature of scientific explanations, and this requires a greater understanding about how teachers and students can generate and evaluate explanations. In addition, dull work with scientific school explanations, it is common for students' alternative' explanations to be pushed by teachers into a conceptual and pedagogical "corner" where it seems that the only way out is to tell the student that the explanation is incorrect and offer the correct one. To register this research in initial teacher training allows guiding the continuity of this research to how practitioners reflect on their interventions in the context of these constructions, with the purpose of promoting reflective practices.

The use of levels of conceptualization enabled an analysis of the practitioners' interventions, constituting a contribution of this study to research on the construction of explanations. We understand that differentiating between these levels of conceptualization, recovering the proposal of Taber[15] and Caamaño Ros[53] offers an interesting interpretation perspective for school scientific explanations, at least in a dual sense. On the one hand, as a didactic device to guide the construction of explanations in the classroom; on the other, allowing the elaboration of a system of categories that allow the teaching practices to be objectified and the development of reflective processes on the practices themselves.

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Conflicts of interest

None.

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