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Teaching in Action: An analysis of teacher and student actions in Physics classes from the perspective of Actor-Network Theory[+*Δ]

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Abstract

In this article, we explore the assumption that the actions of teachers and students in the classroom can be analyzed based on what we call Teaching in Action. Two research questions are raised, one theoretical and the other practical: (1) What is or what could be Teaching in Action? (2) How can we analyze Science Teaching, in this case Physics Teaching, as Teaching in Action? To answer question (1), we transposed the assumptions presented by Latour in the book "Science in Action" to the field of teaching, concluding that Teaching in Action has two faces: a ready made one and the other in the making. To answer question (2), we collected data from recordings of synchronous classes in the discipline of a professional Master's degree at a public university in Paraná. The results for question (2) were divided into two parts. In the first part, we present the episode's categories of teacher and student actions. In the second part, we represent,

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through timelines, the flow of discursive actions throughout the episode, emphasizing, in particular, the controversies that provoked translations by the teacher and students. In the end, except for one student, all the others translated (connected) to the teacher's discourse. The general conclusion is that the phase of the discursive flow in which controversies appear, from the point of view defended in this article, can be adequately characterized as teaching in the making. When most students adhere to (connect) the teacher's discourse, we enter a phase corresponding to ready made teaching, in which controversies cease. In our view, the investigation of actions in the classroom, based on the idea of Teaching in Action, is a promising approach that can be applied to other disciplines and levels of education and even incorporate the actions of non-human actors.

Keywords: *Teaching in Action; Actor-Network Theory; Teacher action; Student action; Physics teaching.*

I. Introduction

In our research on teaching and learning in the classroom through direct observation, developed within the scope of the PROAÇÃO research program (Arruda; Passos; Broietti, 2021), a central question has emerged: how can we understand the connections between teacher actions (actions that the teacher performs in the classroom) and student actions (actions that the student performs in the classroom)? It seems to us that student learning fundamentally depends on such connections; that is, if the actions that the teacher performs are not connected to those that the students perform, it is very likely that student learning will not occur. On the other hand, if the connections between the actions occur, it is very likely that learning is in progress[2]. This is a hypothesis under investigation in our research group[3]. We hope that, with the results presented in this article, it will gain greater plausibility in the eyes of researchers.

Classroom actions (of teachers, students, etc.) can be analyzed based on various research traditions: from the field of Teacher Education, social theories of action, and/or through Actor-Network Theory (ANT[4]) (Arruda; Passos; Broietti, 2021).

In this article we explore the assumption that the actions that unfold in the classroom can be analyzed from what we could call *Teaching in Action*, an idea that is clearly inspired by

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[2] Obviously, we are framing this issue in general terms, without specifying, for now, what we mean by learning.

[3] Education in Science and Mathematics (EDUCIM). Details about the group are available at: http://educim.com.br/.

[4] We prefer to use the acronym ANT here to refer to Actor-Network Theory.

the work *Science in Action: How to Follow Scientists and Engineers Through Society*, by Bruno Latour (1987).

In his book *Science in Action*, Latour sets out to follow scientists and engineers in order to understand how *science in practice* works. The *Teaching in Action* project aims to do something similar, seeking to understand how *teaching in practice* works. If Latour studied science in development, following what scientists and engineers do in their laboratories, we intend to investigate what teachers and students do – especially how their actions connect and disconnect – in our teaching laboratory, which is the classroom.

Regarding the application of ANT to the field of Education and/or Teaching, we can cite: Fenwick and Edwards (2010), who provide a theoretical introduction to ANT and present some applications in Education; Lima, Ostermann and Cavalcanti (2018), who propose a foundation for Science Education based on Latour's ideas; Coutinho and Viana (2019) present several studies relating ANT and Education, both in formal and non-formal spaces; Corrêa *et al*. (2021) conduct a theoretical discussion on ANT and learning; Costa (2023) sought to understand how human and non-human actors were associated in the process of constructing and using a didactic physics experiment; Cher *et al*. (2024) analyze the creation of a research instrument in Science Teaching based on ANT.

Ribeiro and Lima (2022) conducted a systematic literature review (SLR) on the relationship between ANT and Education, using 52 articles published in the Capes Periodicals Portal and the SciELO repository between 2017 and 2021 as a database. They concluded that there is a "lack of recent publications related to the topic in both chosen databases" (Ribeiro; Lima, 2022, p. 14, our translation). Another, more recent SLR, conducted by our group, sought to understand how ANT has been used by Brazilian researchers in the field of Science Education. Based on a corpus of 38 articles, retrieved from Google Scholar, the authors analyzed the objectives of the articles, identifying 8 categories, among them one that related ANT to the classroom and which included 4 articles in Portuguese (Dangui; Arruda; Passos, 2024, p. 404), namely: Oliveira (2008), Coutinho *et al*. (2014), Coutinho *et al*. (2016) and Peron and Guerra (2021). As these articles are more related to the classroom, we will make brief comments about them.

Oliveira's article (2008, p. 101, our translation) presents a "microanalysis of laboratory events, aiming to contribute to the understanding of how the idea of the 'nature' of things is produced" using the concept of articulation for this purpose. Regarding this concept, Latour (1999b, p. 303) states: it is not a matter of knowing "whether or not statements refer to a state of affairs, but only whether or not propositions are well articulated". The study carried out "allowed us to shed some light on the practical activity of the school laboratory and to speculate on a discourse that overcomes the understanding of those events as merely reproducing ideologies and tacit knowledge of an exogenous Science" (Oliveira, 2008, p. 101, our translation).

The article by Coutinho *et al*. (2014) studies children's learning through their practices. Specifically, through ANT the article considers that the child's exploration of the world is not only done through discursive interactions, but also needs to include non-human objects. In this case, it examines the movements performed by various actors in an investigative activity in which a class of five-year-old children from a Municipal Early Childhood Education Unit uses a magnifying glass to observe materials collected in a garden. The results revealed: "(a) the children's engagement; (b) the learning of a new way of seeing the world; (c) the reshaping of the children's identities; (d) the arrival of new elements that changed the patterns of practice in early childhood education" (Coutinho *et al.*, 2014, p. 381, our translation).

The article by Coutinho *et al*. (2016) analyzes a lesson aimed at Youth and Adult Education (EJA)[5]. The lesson, which addressed the history of the Earth and the history of life on Earth, was part of a didactic sequence consisting of 8 lessons, whose main interest was to discuss "the controversy currently occurring in the scientific community about the existence or not of the Anthropocene" (Coutinho *et al*., 2016, p. 185, our translation). Among other results, the authors conclude that the theme (Anthropocene) "is promising for the development of didactic sequences, as it encompasses diverse scientific contente" and for establishing "relationships between the STSE[6] components" (Coutinho *et al*., 2016, p. 191, our translation).

The article by Peron and Guerra (2021) discusses the issue of validating the concept of wave-particle duality proposed by Louis de Broglie from the perspective of Actor-Network Theory and is divided into two parts. In the first part, the authors analyze, through bibliographic research, the "consolidation of de Broglie's wave-particle duality as a black box" (Peron; Guerra, 2021, p. 10, our translation). In the second part, based on the results obtained, the researchers discussed the issue of validating scientific knowledge – in this case, wave-particle duality – with high school students. The results obtained by the authors indicated that "the students questioned views of science that they had expressed at the beginning of the research, among them, the view that mathematical and experimental proof is the only way to validate scientific knowledge" (Peron; Guerra, 2021, p. 1, our translation).

This article, which also focuses on the classroom, differs from those discussed above mainly because it proposes the study of classroom actions based on the idea of Teaching in Action.

From these considerations emerge two research questions, which will be the subject of reflection in this article: *(1) What is or what could be Teaching in Action? (2) How can we analyze Science Teaching, in this case Physics Teaching, as Teaching in Action?*

[5] Youth and Adult Education (EJA) is a modality of Brazilian Basic Education intended for young people and adults over 15 years of age who did not have access to and/or did not complete Elementary School (1st to 9th Grade), as well as foreign migrants who want to improve their learning of the Portuguese Language. More information at: https://educacao.sme.prefeitura.sp.gov.br/educacao-de-jovens-e-adultos-eja/.

[6] Science, Technology, Society and Environment.

These two questions lead to two objectives, each corresponding to one of the research questions. The first seeks to theoretically ground the *Teaching in Action* proposal, based on the ideas of Bruno Latour, John Law, Michel Callon, and other researchers in the field. The second involves testing the idea with data collected in the classroom, which involves studying (following) the actors (actants) and their classroom performances, the connections between them, the stabilization of the didactic-pedagogical network, "examining how these connections came about and what sustains them" (Fenwick; Edwards, 2010, p. 9). In this case, we will follow the steps of the teacher and students in a course taught in a National Professional Master's Program in Physics Teaching (NPMPPT), a topic covered in Section IV.

The remaining sections of the article deal with the rationale behind the *Teaching in Action* idea (Section II), the methodological procedures employed (Section III), the presentation and analysis of the data (Section IV), and the final considerations (Section V).

II. Teaching in Action

First of all, it is necessary to recognize that teaching is always in action. This is because, for it to occur, the teacher must act, the student must act, and when neither of them is acting (at least visibly), some non-human must be acting. This is the case, for example, when the class consists of watching a video. Therefore, *Teaching in Action* is fundamentally related to the actions of teachers, the actions of students, and the actions of non-humans who participate in the course of actions in the classroom.

In part, for the reasons explained in the previous paragraph, that is, in seeking to understand the actions that teachers and students perform in Science and Mathematics classrooms, we ended up encountering Actor-Network Theory as a possible foundation for the research we are developing.

But what is Actor-Network Theory? This is not an easy question to answer, as it is "extraordinarily difficult to write or talk about actor–network theory without either destroying or domesticating it" (Fenwick; Edwards, 2010, p. 1). Latour, for example, states that "there are four things that do not work" in the expression "actor-network theory": "; "the word actor, the word network, the word theory and the hyphen" (Latour, 1999a, p. 15). In the same book, Law defines Actor-Network Theory as:

> *[...] a ruthless application of semiotics. It tells that entities take their form and acquire their attributes as a result of their relations with other entities. In this scheme of things entities have no inherent qualities: essentialist divisions are thrown on the bonfire of the dualisms. Truth and falsehood. Large and small. Agency and structure. Human and nonhuman. Before and after. Knowledge and power. Context and content. Materiality and sociality. Activity and passivity* (Law, 1999, p. 3).

In ANT, there is not, on one side, the actor and, on the other, the network. Actor and network "designates two faces of the same phenomenon" (Latour, 1999a, p. 19). As Ritzer explains:

> *Taking seriously the agency of nonhumans (machines, animals, texts, and hybrids, among others), the ANT network is conceived as a heterogeneous amalgamation of textual, conceptual, social, and technical actors. The "volitional actor" for ANT, termed actant, is any agent, collective or individual, that can associate or disassociate with other agents. Actants enter into networked associations, which in turn define them, name them, and provide them with substance, action, intention, and subjectivity* (Ritzer, 2005, p. 1).

Returning to the theme of action, in *Reassembling the Social*, Latour (2005) not only presents questions very similar to those we have regarding the origins and nature of actions (What is acting? After all, who actually acts, me or others? Are actions conscious?), but also indicates the path to understanding them, that is, by making explicit the connections or associations between things. Examples:

> *The adjective, social does not designate a thing among other things [...] but a type of connection between things that are not themselves social* (Latour, 2005, p. 5).

> *[...] the continuity of any course of action will rarely consist of human-tohuman connections (for which the basic social skills would be enough anyway) or of object-object connections, but will probably zigzag from one to the other* (Latour, 2005, p. 75).

Therefore, in our research, following the ideas of Latour and ANT, we assume that the actions that take place in the classroom involve connections between teachers and students, as well as connections between these actors and objects.

However, we face the problem of understanding what these connections would be, making them explicit and visualizing them. In this article, we seek to show that such connections can be understood through the controversies that open and close during dialogues established between teachers and students in a classroom. The inspiration for focusing on the controversies that arise in the classroom came again from Latour, now in the work *Science in Action* (Latour, 1987). The general idea is that: if Science can be thought of in action, perhaps, with even more reason, Teaching can too.

Thus, conceiving the transposition of "science in action" to "teaching in action" seems viable and desirable, considering that processes in the field of Education present great complexity, given the variety of relationships and connections established between human and non-human actors and, mainly, the controversies that arise in the classroom.

To accomplish this transposition, we will start from the Introduction of the book *Science in Action: How to Follow Scientists and Engineers Through Society* (Latour, 1987)[7], separating points that would be representative of Latour's general idea and that could be transposed to teaching. The author starts from three general assumptions:

(I) Science has two faces: one that is ready made, that knows; and one that is in the making, ignorant, that does not yet know, full of controversies that arise between the various participating actors.

(II) When Science is ready made, its components (general models, equipment, academic support networks, results, etc.) can be considered *black boxes*.

(III) Latour chooses to study Science in construction. To do this, he takes *controversies* as a starting point, but he is also concerned with following how the controversies end.

In *Science in Action*, Latour initially refers to the black box as something that may have a controversial history, complex internal workings, but "about which they need to know nothing but its input and output" (Latour, 1987, p. 3). Later, Latour adds other predicates to the black box, which would be "something that closely resembles an organised whole" unified, whose parts act together, thus a black box exists "when many elements are made to act as one" (Latour, 1987, p. 131).

When science is ready made, we have black boxes. But to understand science still in its infancy, we must go back to the previous stage, to that of *controversies*. This is the moment when a black box is broken, that is, when something that functioned satisfactorily, without generating any kind of questioning, for some reason, begins to be the subject of disagreement. When the black box is opened by controversies, it is possible to see the actors moving, (re)aggregating, forming and dissolving groups.

Venturini (2010, p. 260) states that "the word controversy refers here to every bit of science and technology which is not yet stabilized, closed or 'black boxed'", defining it as follows:

> *[...] the definition of controversy is pretty straightforward: controversies are situations where actors disagree (or better, agree on their disagreement). The notion of disagreement is to be taken in the widest sense: controversies begin when actors discover that they cannot ignore each other and controversies end when actors manage to work out a solid compromise to live together. Anything between these two extremes can be called a controversy* (Venturini, 2010, p. 261).

But what would *Teaching in Action* be? How to arrive at a conception that has not yet been formalized? This would be the general problem, to which this article attempts to provide a consistent answer. The three assumptions (I), (II) and (III) of Latour, mentioned, indicate how

[7] *Science in Action*, originally published in English by Harvard University Press in 1987.

to transpose the idea of *Science in Action* to Teaching. In this sense, *Teaching in Action* would also start from three general assumptions:

(i) Teaching has two faces: a *ready made* one, which knows, exemplified by predefined content, educational theories and methodologies, widely accepted by the teaching community; and one *in the making*, uncertain, in which the teacher has to deal daily with the challenges of the classroom and with the *controversies* that arise between the various participating actors.

(ii) When teaching is ready made, its components (content, methodologies, activities, teaching materials, equipment, academic support networks, assessments, etc.) can be considered *black boxes*: nothing needs to be known about them, only what goes in and what comes out. There can be no controversy.

(iii) In Teaching in the making, in motion, we take, as Latour did, the *controversies* that arise in the classroom as a starting point. Likewise, we will also be concerned with following how the controversies end.

To conclude this section, let's briefly discuss another ANT term we used in this article – translation – a concept that is "related to transformation and displacement" (Cher *et al.*, 2024, p. 6, our translation). Latour writes: "the operation of translation consists of combining two different interests [...] to form a single composite goal" (Latour, 1999b, p. 88).

Callon (1984) defined the concept of translation when he analyzed a group of specialists (fishermen, researchers) who studied scallops[8] and their harvest. The author writes:

> *[...] the notion of translation emphasizes the continuity of the displacements and transformations which occur in this story:displacements of goals and interests, and also, displacements of devices, human beings, larvae and inscriptions [...]. To translate is to displace* (Callon, 1984, p. 223).

Translation can also be defined as indicated below, and it approximates the definition we considered for the development of the research, the results of which are presented in this article.

> *Translation is the term used by Latour (1987) to describe what happens when entities, human and non-human, come together and connect, changing one another to form links [...]. Entities that connect eventually form a chain or network of action and things, and these networks tend to become stable and durable. At each of these connections, one entity has worked upon another to translate or change it to become part of a collective or network of coordinated things and actions* (Fenwick; Edwards, 2010, p. 9).

[8] The scallop is a marine bivalve mollusk.

III. Methodology

In the research reported here, data were collected through recordings of classes (remote and in-person) from the course "Physics in Elementary Education from a Multidisciplinary Perspective" which is part of the National Professional Master's Program in Physics Teaching (NPMPPT) at a state university in Paraná. The course was structured with a workload of 60 hours and was taught in the first semester of 2022. All classes were recorded and subsequently transcribed.

We selected episodes from some classes, entitled: *(a) Formation of light in mercury vapor lamps, (b) Atomic model, (c) Tungsten lamps, (d) Guidance of student L,* and *(e) Restructuring of the content of Paraná's high school curriculum*.

We inform that all methodological procedures have been approved by Ethics Committees, including the Ethics Committee of the State University of Londrina. The data established for this article refer to the project *The teaching and learning of science and mathematics in the classroom and in informal environments*, under number CAAE 57663716.9.0000.5231, n. 4.776.535, in effect during data collection.

In this article we consider only episode *(a) Formation of light in mercury vapor lamps*, taken from the classes of 03/03/2022 and 10/03/2022, which dealt with the content Light and Vision. This class, of the synchronous type, took place remotely, via the *Google Meet* application.

Based on the episode selection, the following analytical procedures were performed:

(1) Fragmentation of the text and organization of the units of analysis.
(2) Categorization of the teaching and learning actions found in the episode.
(3) Selection of the dialogues that highlighted the controversies.
(4) Graphic representation of the controversies.

In procedures (1) and (2) we used Content Analysis (Bardin, 2021). In procedures (3) and (4) we considered the principles of the Cartography of Controversies (Venturini, 2010).

Content Analysis (CA) can be summarized as a set of methodological tools that are constantly being improved and can be applied to any discourse. In general, the steps of Content Analysis are as follows: 1) pre-analysis, which includes defining the problem/objectives, choosing and organizing the material; 2) exploration of the material, which includes coding and categorizing the units of analysis; and 3) analysis and interpretation of the categories.

Regarding the Cartography of Controversies (CC), according to Venturini (2010), it helps us to capture the complexity of society, and the only thing to do is to follow the steps of the actors while the controversy is still active. Venturini advises: avoid cold controversies, that is, controversies that are no longer being debated, that have ceased to have movement; avoid past controversies, that is, current controversies allow for better work, unless it is possible to move to that moment through precise records; avoid unlimited controversies, that is, due to the complexity of the controversies, it is possible that some will become larger and more complex; avoid subterranean controversies, that is, controversies that are not accessible.

Although CC may be averse to methodological determinism and dogmatism, we understand that the use of CA and its stages does not clash with it or with ANT; on the contrary, it presents itself as an additional resource, especially for dealing with texts, which are abundant traces left by the actors.

The analyses presented in the next section focus on so-called *speech acts* or *acts of language*, which are defined as follows:

> *In the philosophical tradition that goes back to scholasticism, an act is understood as "that which makes something be": acting is thus identified with "making something be" and corresponds to the passage from potentiality to existence.* (Greimas; Courtéz, 2021, p. 42, our translation).

> *The general definition of an act applies to the act of language (also called a speech act) [...]. Considered as a specific doing, the act of language first appears as a "knowing-making", that is, as a doing that produces the conjunction of the enunciated subject with an object of knowledge [...]. On the other hand, the act of language, as doing, presents itself as a "making-being": what it calls into existence is meaning [...]. Finally, the act of language can be considered as a "doing-to-do", that is, as a manipulation, through speech, of one subject by another subject.* (Greimas; Courtéz, 2021, p. 43-44, our translation).

With regard to action, the same authors define it based on the concept of an act:

> *Action can be defined as a syntagmatic organization of acts, without us having to pronounce in advance on the nature of this organization: ordered sequence, stereotyped or programmed by a competent subject. [...] Narrative semiotics does not study actions themselves; it studies 'role actions', that is, descriptions of actions.* (Greimas; Courtéz, 2021, p. 18, our translation).

To conclude this section, it is important to clarify how we are using ANT in this research. We know that ANT is not a "theory" in the traditional sense of the term and that it could perhaps be considered "as much a method as a theory" (Ritzer, 2005, p. 2) or "a way to intervene, not a theory of what to think" (Fenwick; Edwards, 2010, p. 1). We are also aware that we are not conducting an ethnography of the classroom in the ANT sense. So how is ANT being used in this article?

We believe that books, articles, etc., dealing with ANT, after being published, can be considered as an object-knowledge (Charlot) or as an inhabitant of world three (Popper). For Charlot (2000, p. 75, our translation), object-knowledge is "knowledge itself, as objectified, that is, when it presents itself as an intellectual object, as a referent of a content of thought". Popper (1975, p. 152, our translation), on the other hand, postulates the existence of three worlds: the material world, the mental world, and the world of ideas in the objective sense, that is, "the world of theories in themselves and their logical relations".

This authorizes us, as researchers, to take the texts of ANT as object-knowledges, inhabitants of world three, and use them as inspiration for the creation of new ideas in the field of Science Education. We do not necessarily need to do ethnography to use ideas and concepts from ANT in our research. What matters to us is whether new ideas can be created from the concepts of ANT.

In summary, in this article, based on Foucault, we take the ideas of ANT as a toolbox:

> *My discourse is, evidently, an intellectual discourse and, as such, operates within the existing power networks. However, a book is made to serve uses not defined by its author. The more new, possible, unforeseen uses there are, the happier I will be. All my books [...] can be small toolboxes. If people really want to open them, to use such a phrase, such an idea, such an analysis, like a screwdriver or a wrench, to create a short circuit, to disqualify, to break the power systems, including, eventually, the very systems from which my books resulted... well, so much the better!* (Foucault, 2006, p. 52).

Next, we present the results of the analyses.

IV. Results

In the next two subsections, we present two types of results. In Subsection IV-1, we present the categories of teacher and student actions found, and in Subsection IV-2, the representations of the connections between teacher and student actions, which are evidenced through the establishment and resolution of controversies that occur during the discursive flow.

At this point, we are only dealing with the connections between the speech acts of human actors.

IV.1 Categories of teacher and student actions

After the text fragmentation process – analytical procedure (1) we carried out the grouping and categorization of the actions of the two groups, teacher and students – analytical procedure (2)[9].

The text fragments (Analysis Units – AU) from the aforementioned episode were entered into a spreadsheet to facilitate the categorization of the actions of the subjects involved. Since the aim was not only to understand the actions of the teacher and the students, but also to highlight the connections that occurred during the class episode – based on the controversies established – the texts of the speeches were separated, with one column for the teacher's

[9] We would like to inform that categorizations of teacher and student actions have been carried out in the research group for approximately 15 years. A very large amount of information has been collected and organized during this period. Therefore, within the scope of this article, we are unable to discuss the origins, criteria, and limitations of the categories used.

speeches, with its respective categorization column, and another column for the students' speeches, with its respective categorization column, as shown in Table 1.

Each text excerpt was encoded, resulting in a character sequence as follows: code "1aD" where the first character represents the sequential numbering of the excerpt; the second, the episode to which the excerpt refers (in this case, *a*); and finally, the speaker (in this case, D, the teacher). The same procedure was performed with the text fragments of the students' speeches, resulting in the following form: code "1aH" containing the sequential numbering of the article, the episode to which the excerpt belongs, and the code of the speaker (in this case, student H).

Table 1 – Example of data organization.

Teacher action	**Code**	**Teacher excerpt (AU)**	**Student action**	**Code**	**Student excerpt (AU)**
To question	1aD	Have you ever heard of concept maps, H and K?	To agree	1aH	Yes, but I have never done it.
To guide	2aD	So, in the last class, LF, S, and M did their assignments and already handed them in. Now, since we are doing them remotely, I want you to do yours, take a picture, and send it to me. What I am asking is that you create a map, starting from a natural event that covers a large part of the content of this subject.	To clarify doubts	2aK	Is one of the topics appearing on the screen related to Biology, Chemistry, or the other topics I have here?
To re-explain	3aD	Well, I don't think I was very clear. I want you to start creating a conceptual – or mental – map of a phenomenon that encompasses much of what is presented here.	To affirm	3aK	I got it.
To question	4aD	Do you have any idea of a phenomenon that could be used, one that involves much of what has been presented there?	To comment	4aH	Ah, from what I'm seeing here, it is more a matter of energy, right... Light... then it goes to the nanoscale. Particles and so on. I believe so.

Source: The authors.

The categories of teacher actions are presented in Table 2, and the categories of student actions in Table 3.

Table 2 – Categories of Teacher Actions.

Category	Definition	Excerpt
To explain	The act of elucidating, clarifying, or developing a concept, content, or procedure for students.	22aD, 23aD, 24aD and 27aD
To guide	The act of providing guidelines or instructions for carrying out a task, activity, or project.	2aD, 8aD, 9aD and 11aD
To question	The act of provoking reflection among students by stimulating reasoning and active participation.	1aD, 4aD, 5aD, 7aD, 10aD, 12aD, 13aD, 14aD, 17aD, 18aD, 19aD, 20aD, 21aD, 25aD and 26aD
To re-explain	The act of revisiting a previous explanation, reformulating its form, adapting or reinforcing ideas to ensure student comprehension.	3aD and 6aD
To recall	The act of attempting to activate prior knowledge by reinforcing important information.	15aD
To suggest	The act of providing recommendations or proposing alternatives in a given situation.	16aD

Source: The authors.

Similarly, the same process was carried out for the students' statements, resulting in the action categories shown in Table 3.

Table 3 – Categories of Student Action.

Category	Definition	Excerpt
To affirm	The act of stating an idea, giving a response, or defending a point of view.	3aK, 27aL, 28aS, 30aL, 37aS and 38aL
To comment	The act of reacting to the speech or comments of the teacher or colleagues..	4aH and 13aH
To complement	The act of expanding, developing, or elaborating on an idea, concept, or explanation.	33aH and 34aH
To conclude	The act of making assertive inferences about presented information or knowledge.	40aS
To agree	The act of corroborating or endorsing an expressed idea, validating it.	1aH, 16aH and 29aL

To clarify doubts	The act of seeking to resolve uncertainties or misunderstandings that arise during class.	2aK, 15aH and 20aS
To explain with flaws	The act of presenting ideas, concepts, or processes in an incomplete or inconsistent manner.	35aH
To expose	The act of presenting ideas, information, or results to the group.	14aH
To not remember	The act of realizing one cannot remember something specific during class.	32aLF
To deny	The act of issuing a negative response to a question posed by the teacher.	24aL and 25aS
To question	The act of seeking clarification of doubts about something from the teacher.	39aS
To reflect	The act of conducting an analysis or evaluation of a particular piece of information or circumstance.	5aH, 6aH, 17aH, 18aH, 19aH and 23aH
To answer incorrectly	The act of providing an answer where the content does not match the expected answer.	31aL
To suggest	The act of proposing ideas, solutions, or alternatives in a given situation.	36aL
To suppose	The act of presenting a hypothesis or conjecture based on partial knowledge, without definitive certainty.	7aK, 8aH, 9aK, 10aK, 11aH, 12aH, 21aS, 22aM and 26aL

Source: The authors.

From Table 2, it is possible to infer that the teacher actions are quite concentrated in one category, “To question”. The actions in this category represent moments in which the teacher attempts to promote reflection among students through questioning; therefore, in this episode, this practice is evident, in which the pursuit of student engagement and reflection is triggered by an action of the teacher. On the other hand, when observing the set of student actions during the episode (Table 3), the same characteristic is not found, that is, there is no concentration of student actions in a specific category, with the categories with the highest incidence being: “To suppose”, “To affirm” and “To reflect”

We will explain below how these categories connect during the episode *(a)*.

IV.2 Connections between teacher actions and student actions

After analyzing the data in the spreadsheet created for the accommodation and categorization of the excerpts, we sought to demonstrate the connection between teacher and student actions, as explained in procedures (3) and (4).

The aim was to present the dynamics of the speech acts in the classroom episode. To this end, we created a *timeline* for each episode, which includes the teacher's and students' speech, the categories of action, and the controversies perceived in this process, in chronological order. The changes in each actor's trajectory on the timeline also indicate the shifts that each of them made in the episode, especially teacher D.

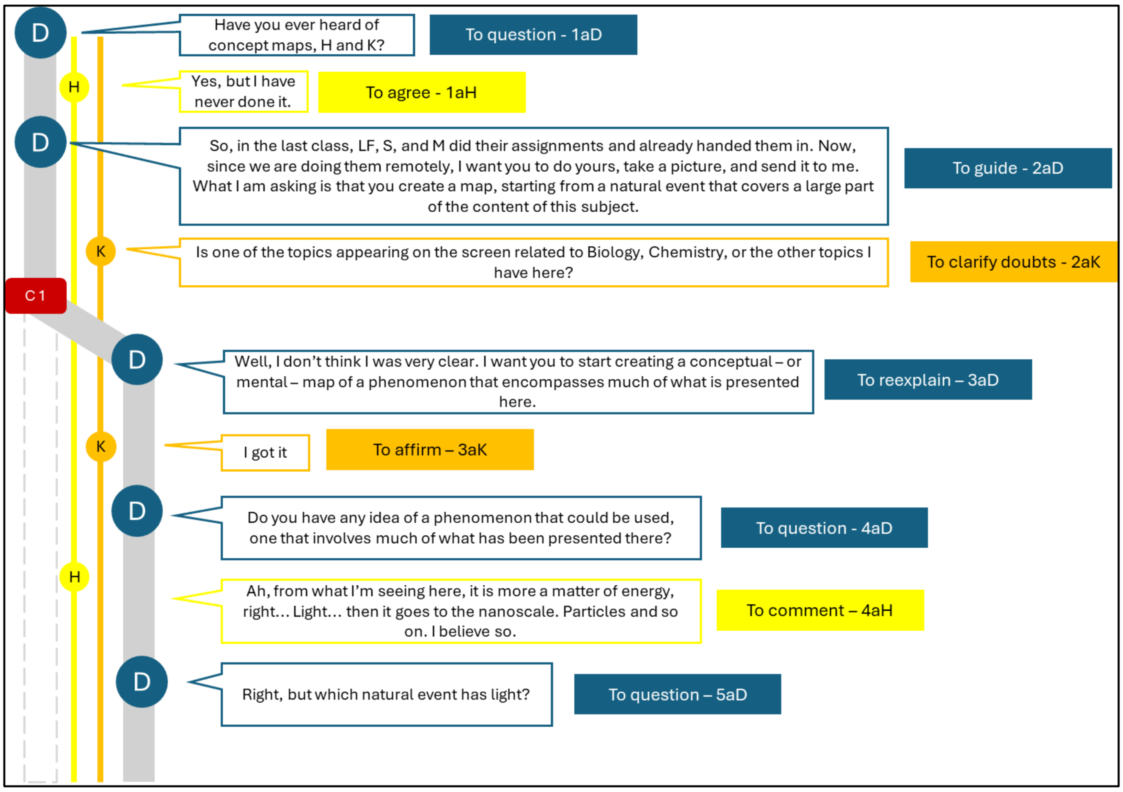

Fig. 1 – Timeline of episode (a) – part 1. Source: The authors.

Fig. 1 shows the first moment of the episode studied. In this image, the blue circle marked D represents the teacher; the gray band, in which the circle is inserted, represents the path they took; and the blue box shows their speech at that moment. Similarly, each student is represented by a circle, a code for their name (H, K, etc.), the path they took, and a box with their speech at those moments. There is also a red rectangle, which indicates the moment of controversy.

The teacher begins the class by giving instructions on an activity to be carried out (making a concept map). K's comment indicates that the instruction was not understood. As previously mentioned, Venturini (2010, p. 260) states that these moments of "shared uncertainties", of controversies, are the moment in which the cartographer of the social acts. K's lack of understanding interrupts the flow of the class, creating a barrier to its continuation, instigating a teaching-learning controversy, that is, a moment in which there is a dissonance between the expectations of the teacher (to teach) and the students (to learn).

The controversy that arose (C1) causes the teacher to deviate from their plan of action and change the course of the lesson (translation), while K and H continue on their route. Instead of explaining again, the teacher uses the strategy of questioning the students so that they reach conclusions.

Let us now consider part 2 of episode (a), as shown in Fig. 2.

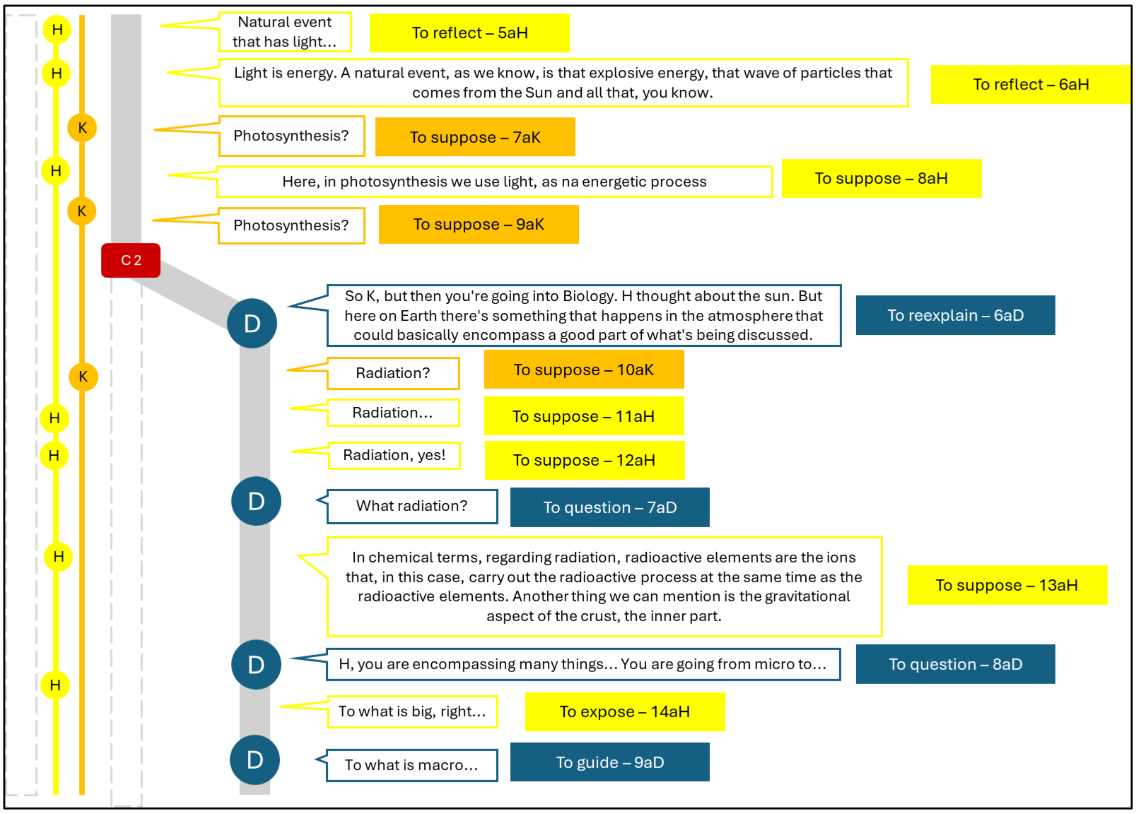

Fig. 2 – Timeline of episode (a) – part 2. Source: The authors.

At the end of Fig. 1, D asks: "Which natural event has light?". Students H and K attempt some answers, but the assumption "photosynthesis" causes another change of course for the professor (controversy C2). The professor does not want to go into the field of Biology and seeks to keep the discursive flow in the field of Physics. However, the word "radiation" mentioned by K and H also ends up leading to the subject of radioactivity and even gravitation, straying from the direction that D tries to take the discussion. But D remains firm in their trajectory until the end of the episode (a), as we will see in the following figures.

The continuity of the discursive flow from Fig. 2 continues in Fig. 3. At a certain point, students S and M enter the conversation, immediately connecting to the discourse initiated by Professor D based on controversy C2. Perceiving the association between S and M and the teacher's discourse, H performs a translation and adheres to the dominant discourse. Let's look at Fig. 4.

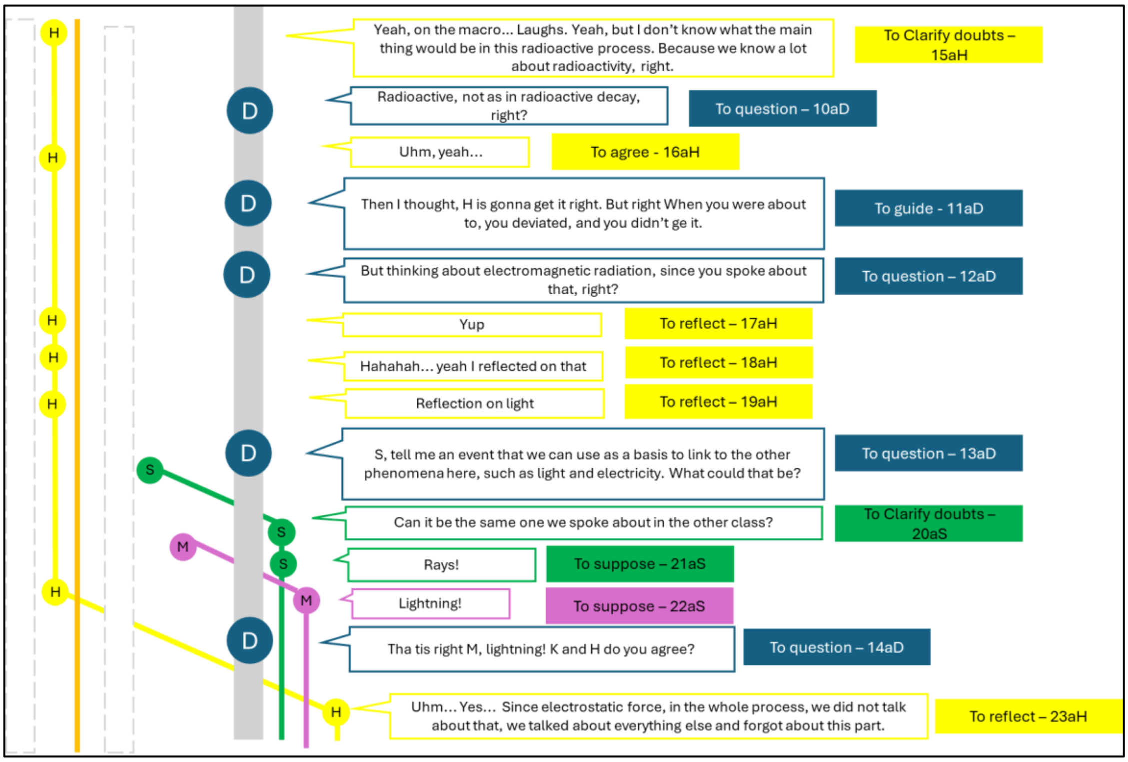

Fig. 3 – Timeline of episode (a) – part 3. Source: The authors.

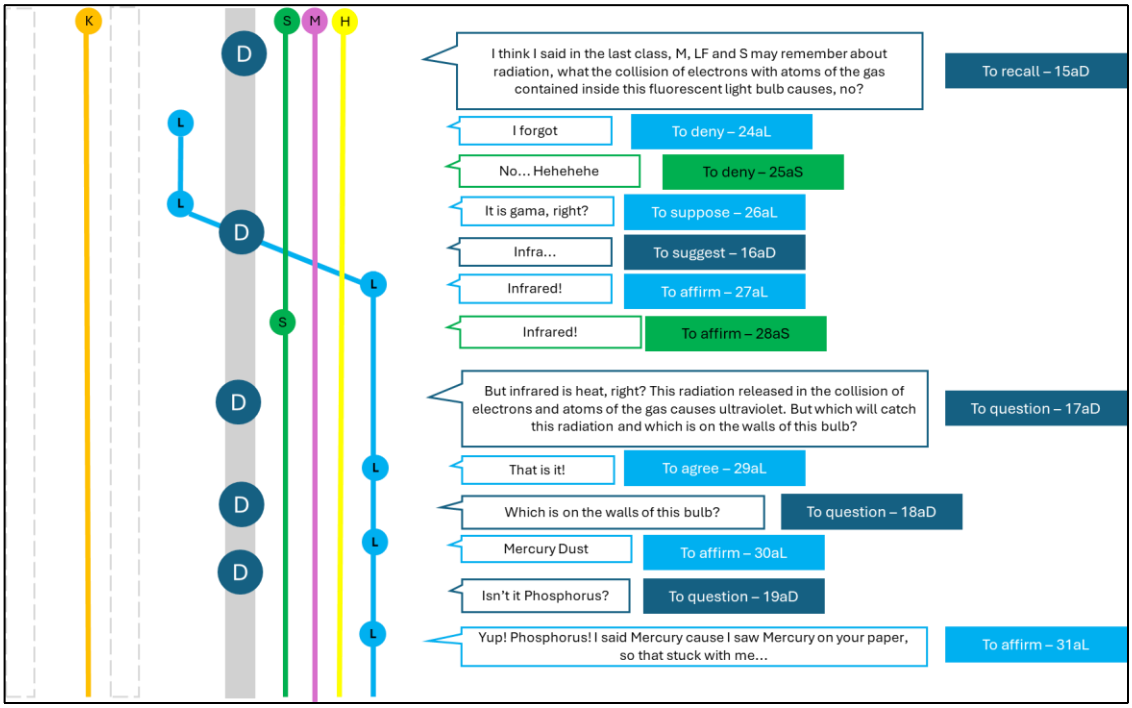

Fig. 4 – Timeline of episode (a) – part 4. Source: The authors.

Fig. 4 shows, right from the start, the connection of students S, M, and H to Teacher D's speech. Then L enters the scene, immediately joining the group formed by D, S, M, and H. Only K does not speak up and, apparently, remains isolated (disconnected) until the end of the episode (a), as we can see in Figs. 5 and 6.

Finally, in the last stage of the episode (a), it is noticeable that all the students' speeches are connected to the teacher's discourse, except for K who, as shown in Figures 3, 4, 5 and 6, no longer participates in the episode. The teacher maintains the strategy of questioning the students, waiting for their answers to make any necessary course corrections. The students participate in the class in a more reflective way.

In this way, we were able to map an episode that occurred during a class, representing the actions taken by the actors involved, based on the controversies that arise and the students' adherence (connection) to the teacher's discourse.

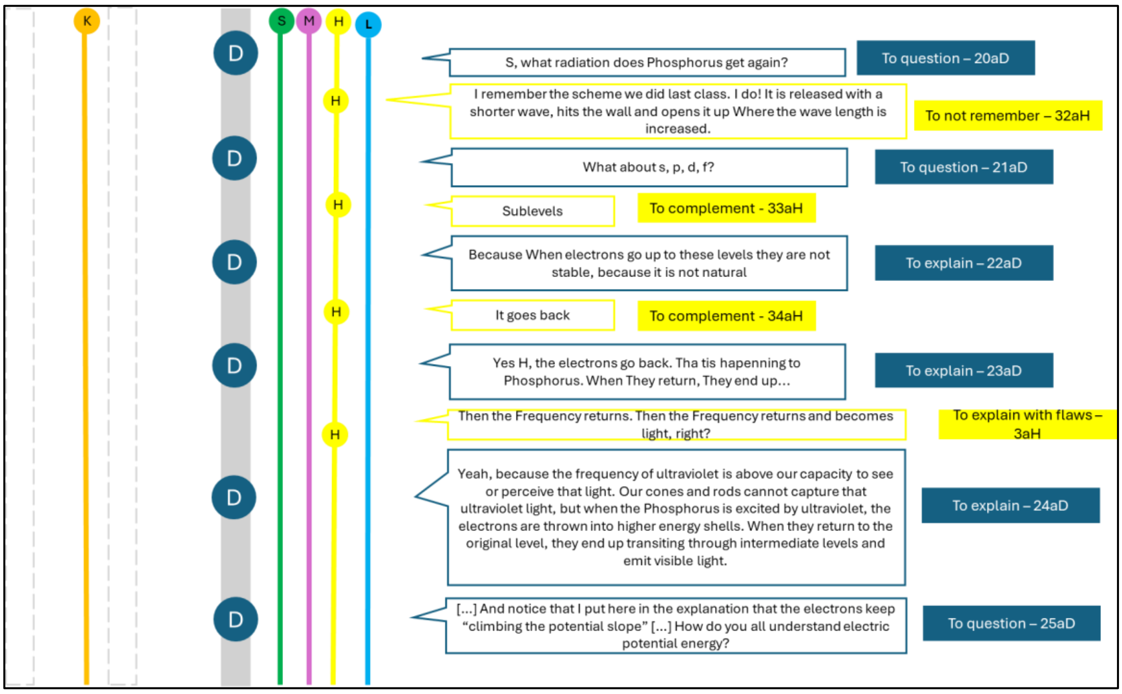

Fig. 5 – Timeline of episode (a) – part 5. Source: The authors.

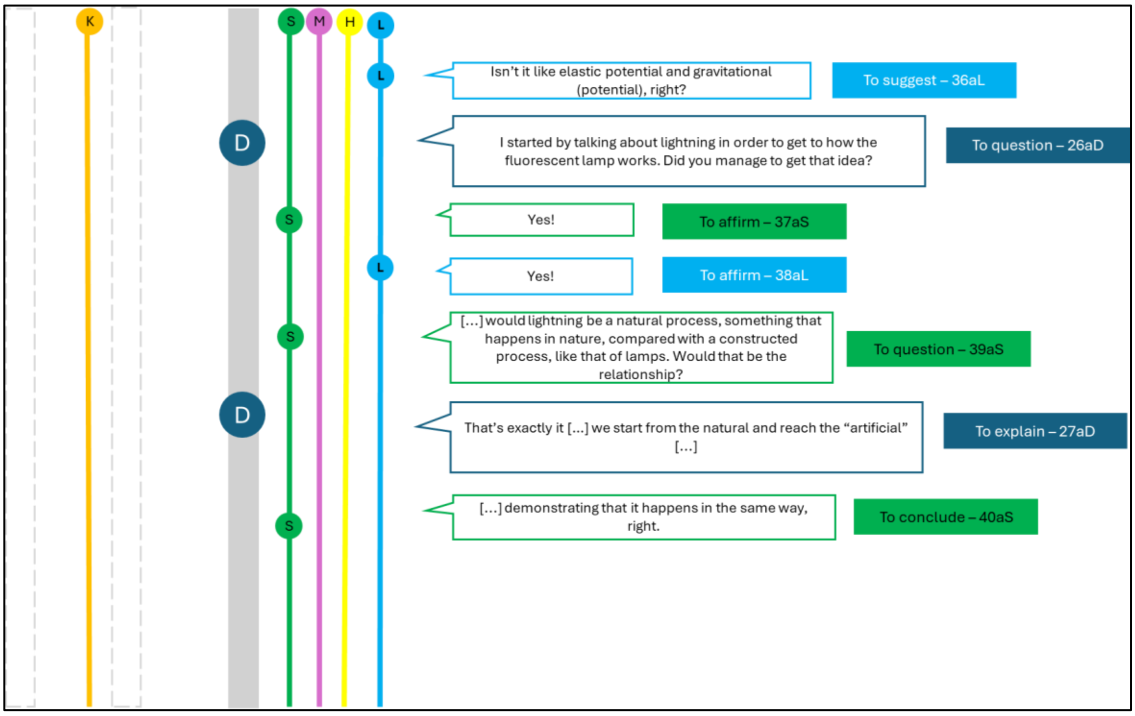

Fig. 6 – Timeline of episode (a) – part 6. Source: The authors.

V. Final Considerations

We began this article by posing two research questions. Question (1), more theoretical, inspired by the ideas of Actor-Network Theory, asks what *Teaching in Action* could be. Question (2), more practical, focuses on the application of this idea to Science Education.

To answer question (1), we transposed the assumptions presented by Latour in the book *Science in Action* to the field of Education, concluding that *Teaching in Action* has two faces. There is *ready made teaching*, with diverse knowledge related to disciplinary content, educational theories, curricula, methodologies, teaching materials, etc., accepted by the teaching community and educational institutions, which guide classroom practices. The teacher, before entering the classroom, certainly knows a large part of this knowledge and uses it in their planning. The knowledge that makes up the ready made face of Teaching is like a black box. There is little controversy about it.

However, when the teacher is implementing their lesson plan in the classroom, controversies may arise. Students may not understand a particular concept, may disagree on the answer to a problem, or may have difficulty understanding the results of an experiment. The teacher must reflect *in actu*, that is, during the actions that take place in the classroom. This is, in this case, *teaching in the making*.

In short, *Teaching in Action* is like a coin with two sides: one ready made and the other in the making. This is the answer to the first question of the article.

If the first question is theoretical, the second is practical. The second question, of course, does not have a general answer. For each context analyzed, for each case, the sequence of actions in the classroom is different. But, if we look for the connections between teacher and student actions, identifying the controversies seems fundamental to understanding what *teaching in the making* would be.

In this article we focus on episode *(a) Light formation in mercury vapor lamps*, in a synchronous class of a professional master's program. Although the flow of discursive actions or flow of *speech acts* in the episode can be understood as a whole, it has been separated into six parts to facilitate the explanation of the analyses for the reader.

The results were separated into two parts. In the first part, we present the categories of teacher and student actions found in the episode. In the second part, we represent, through timelines, the flow of discursive actions throughout the episode, emphasizing, in particular, the controversies that provoked shifts in the teacher's and students' discourse. In the end, with the exception of student K, all students shifted (connected) to the teacher's discourse.

The overall conclusion is that the phase of the discursive flow in which controversies appear, from the point of view defended in this article, can be adequately characterized as *teaching in the making*. From the moment the majority of students adhere to (connect with) the teacher's discourse, we enter a phase that would correspond to *ready made teaching*, in which controversies cease.

It is impossible not to relate *ready made teaching* with convergent thinking and *teaching in the making* with divergent thinking, revealing yet another aspect of the "essential tension" experienced by the science teacher, as described in Arruda *et al*. (2005).

Ready made teaching seems to coincide very well with scientific learning described by Thomas Kuhn as "an initiation into an unequivocal tradition" (Kuhn, 1977, p. 228), highlighting its characteristic as convergent thinking:

> *Without defending plain bad teaching, and granting that in this country the trend to convergent thinking in all education may have proceeded entirely too far, we may nevertheless recognize that a rigorous training in convergent thought has been intrinsic to the sciences almost from their origin* (Kuhn, 1977, p. 228).

On the other hand, the moments when controversies arise – *teaching in the making* – could be identified with divergent thinking. In this case, there would not be a single paradigm guiding reflections and discursive actions: teachers and students can disagree, both on concepts and on general issues related to teaching.

In our view, investigating classroom actions based on Actor-Network Theory or, more specifically, *Teaching in Action*, seems to be a promising approach. In the case analyzed here, the controversies were always related to questions raised by the students. But it doesn't always have to be that way. Controversies about the meaning of a concept, the resolution of a problem, or the results of an experiment can also occur in physics classes, but they are perhaps rarer.

What developments can we foresee for *Teaching in Action*? First of all, it is a research program that, broadly speaking, aims to apply the concepts of Actor-Network Theory to teaching, that is, to the classroom. A program that, taking ANT as its theoretical and methodological basis, intends to investigate: the flow of actions that unfold in science classes, not only in Higher Education, but also in Primary and Secondary Education; the connections that are established and broken (opening and closing of black boxes) and the evolution of controversies during classes; the participation of non-humans in the flow of actions, etc.

From a theoretical point of view, the relationship between the idea of *ready made teaching* and *teaching in the making*, and Kuhn's propositions that the development of science oscillates between convergent and divergent thinking, would be areas to be explored.

Specifically regarding physics classes, the next steps would consist of analyzing, using the same theoretical and methodological framework described in this article, classes that address other physics content and experimental (laboratory) classes.

We acknowledge that this article does not consider the actions of non-humans, but only the discursive interactions between human actors. This is a first approach to understanding what Teaching in Action could mean. The study of the course of actions is complex, and in this case, we prioritize connections only between humans because we only address the *speech acts* established between the teacher and the students. A comprehensive study, including non-humans, should be developed later.

Certainly, these investigations, which will be the subject of future research, should have implications for teaching, learning, and teacher education in science and perhaps other areas. At the moment, however, we do not yet have an answer as to the potential impact of our research on the field.

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