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ESCOLA DE FÍSICA CERN: UMA ANÁLISE DO DISCURSO
À LUZ DA EPISTEMOLOGIA DE LUDWIK FLECK

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ARTICLE

CERN PORTUGUESE LANGUAGE TEACHERS PROGRAM: A DISCOURSE ANALYSIS FROM THE POINT OF VIEW OF LUDWIK FLECK'S EPISTEMOLOGY

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ABSTRACT:

In this study, Ludwik Fleck's epistemology is used to interpret the socialization of knowledge between scientists and teachers participating in a short course called "CERN Portuguese Language Teachers Program". We argue that the two groups of subjects whose interaction is investigated — CERN scientists and high school physics teachers — constitute a single thought collective, with CERN researchers comprising the esoteric circle and the teachers comprising the exoteric circle. The interactions between these two circles occur through intracollective communication, and the socialized knowledge is mostly scientific, not pedagogical, and inscribed in the discursive formations of the sciences of journals and handbooks.

Keywords:
Ludwik Fleck; CERN Portuguese Language Teachers Program; teacher-scientist partnership.

ESCUELA DE FÍSICA CERN: UN ANÁLISIS DEL DISCURSO DESDE EL PUNTO DE VISTA DE LA EPISTEMOLOGÍA DE LUDWIK FLECK

RESUMEN:

Este trabajo utiliza la epistemología de Ludwik Fleck para interpretar la socialización del conocimiento entre científicos y profesores que han participado de un curso de corta duración llamado "Escuela de Física CERN". Se sostiene que estos dos grupos de sujetos, científicos del CERN y profesores brasileños de física de Enseñanza Media, constituyen, según el análisis de la interacción, un único colectivo de pensamiento. Los científicos estarían en el círculo esotérico de interacción, ya los profesores estarían en el círculo exotérico. Las interacciones entre estos dos círculos ocurren a través de circulaciones intracolectivas de ideas, y los conocimientos socializados son mayoritariamente científicos (y, además, no pedagógicos), siendo inscritos en las formaciones discursivas de las ciencias de revistas y de los manuales.

Palabras clave:
Ludwik Fleck; Escuela de física CERN; interacción profesor-científico.

ESCOLA DE FÍSICA CERN: UMA ANÁLISE DO DISCURSO À LUZ DA EPISTEMOLOGIA DE LUDWIK FLECK

RESUMO:

Neste trabalho a epistemologia de Ludwik Fleck é empregada para interpretar a socialização do conhecimento entre cientistas e professores participantes de um curso de curta duração denominado "Escola de Física CERN". Defende-se que esses dois grupos de sujeitos, cien-

Palavras-chave:
Ludwik Fleck; Escola de Física CERN; interação

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tistas do CERN e professores brasileiros de Física, do Ensino Médio, constituem, segundo a análise da sua interação, um único coletivo de pensamento. Os cientistas estariam no círculo esotérico e os professores no círculo exotérico. As interações entre esses dois círculos ocorrem por meio de circulações intracoletivas de ideias, sendo que os conhecimentos socializados são majoritariamente científicos (e, ademais, não pedagógicos), estando inscritos nas formações discursivas das ciências dos periódicos e dos manuais.

professor-cientista.

INTRODUCTION

The CERN Portuguese Language Teachers Programme (EF-CERN) is a short-term course for in-service basic education physics teachers. It takes place at the premises of the European Organization for Nuclear Research (CERN) and is taught by the scientists linked to it. EF-CERN offers intensive training, distributed, and organized over a week[1], which takes place in the second semester of each year and with a total workload of 60 hours/class. Since 2009, the course has been attended by more than 200 Brazilian professors (Abreu, 2015). The EF-CERN program consists of lectures on research developed at CERN and open topics in particle physics, as well as a theoretical mini-course involving topics of nuclear and particle physics. Technical visits to CERN facilities are also planned, such as the data processing center, detectors, and accelerators, including the Large Hadron Collider (LHC) (Garcia, 2015). A workshop involving the making of a cloud chamber using low-cost materials is also offered. The edition of EF-CERN in which Brazilian teachers participate is taught in Portuguese and has the presence of teachers from other Portuguese-speaking countries.

Although it has already been offered on several occasions, there are few studies that investigate the effects of EF-CERN on the professional development of its participants. As examples, we highlight the work of Londero (2014) who analyzed the characteristics of the approach to particle physics in the classroom by teachers participating in EF-CERN and the work of Denardin et al. (2019), which mapped the evolution of the academic-professional profile of 103 participants of the course. Furthermore, Costa et al. (2021) analyzed the learning evidence of an EF-CERN participant in the light of the research teacher's learning focuses.

In this vein, this work aims to interpret the socialization of knowledge between scientists and professors who participated in EF-CERN in the light of Ludwik Fleck's epistemology. To this end, teachers from two different editions of EF-CERN were interviewed and their discourses analyzed using the French Discourse Analysis (AD). Some works in science education have already discussed the articulation between Fleck's epistemology with DA (Nascimento, 2005) or with Bakhtin's theory (Setlik & Silva, 2021). The former made use of articulation to understand scientific dissemination, while the latter proposes an analytical trajectory for texts that explore scientific knowledge.

Fleck's epistemology is justified as a theoretical reference for this work, since the author seeks to elucidate the traffic of ideas and practices in a certain area of knowledge between specialists, professionals with general education and lay people. The author understands knowledge not only as a social and historical product since a subject takes presuppositions of a particular collective form of perception (active couplings) to the field of knowledge. However, there are also what Fleck calls passive couplings that are inevitable results and are independent of social, historical, and state of knowledge aspects, being "perceived as objective reality" (Fleck, 2010, p.83). In addition, Fleck presents categories such as collective and Thought styles, eso and exoteric circles and intra and inter-collective communication of ideas, concepts relevant to the understanding of interactions within the scope of EF-CERN.

Fleckian epistemology has been used as a theoretical support for Brazilian research in science education since the 1990s (Lorenzetti et al., 2013) and literature reviews such as that of Lorenzetti et al. (2018) and Souza & Martins (2021) indicate the relevance of its use in the area. As examples, Fleckian theory has been used to analyze teaching practice and teacher training (Gonçalves et al., 2007); to explore aspects associated with scientific communication and dissemination (Nascimento, 2005; Nobre-Silva & Silva, 2020); to analyze the emergence of scientific facts such as the use of insulin in diabetic patients (Heidrich & Delizoicov, 2009) or in Joule's attempt to replace the steam engine with the electric one (Queirós et al., 2014;) and articulated with the era of post-truth (Martins, 2020a; Saito, 2020).

THE EPISTEMOLOGY OF LUDWIK FLECK

Much of Ludwik Fleck's epistemological theory is concentrated in his book Genesis and Development of a Scientific Fact, published in 1935; however, the author discusses the philosophy of science in other articles (Martins, 2020b).

For Fleck (2010) knowledge is a social product par excellence and science develops collectively; so that the "bearer of knowledge is a well-organized collective, which far surpasses the capacity of an individual" (p. 85). One of the fundamental concepts of his theory is the Thought style (EP), which can be understood as a:

> [...] directed perception in conjunction with the corresponding processing on the mental and objective plane. This style is marked by common characteristics of the problems that interest a collective of thought; of judgments, which he considers as self-evident, and of methods, which he applies as means of knowledge. It is eventually accompanied by a technical and literary style of the knowledge system (Fleck, 2010, p. 149).

The EP can be understood as the set of practices and knowledge common to a particular collective of thought (PC). PCs refer to groups of individuals from a certain field of knowledge who develop a certain type of complicity by thinking in a similar way. The CP is the community bearer of the EP, in which techniques, jargon and specific and consensual terms of that EP are socialized, forming a system of specific codes and an ideal cult of truth (Fleck, 2010).

For Fleck (2010), the PCs are not homogeneous, but formed by the esoteric and exoteric circles, each one of them consisting of several layers. The esoteric circle is more closed and formed by specialists. It is where knowledge of a particular area is produced. Around it is the exoteric circle, made up of lay people, educated laymen, in short, public opinion in general. In it, the knowledge produced by specialists is stylized, simplified, and disseminated in different ways (Fleck, 2010). The circles of a PC are related based on reliability and trust in experts, on the one hand, and on the dependence of public opinion, on the other (Fleck, 2010). Thus, there is a relationship of interdependence between the eso and exoteric circles that strengthen the EP, since "popular knowledge is what form's public opinion about specialized knowledge, crystallizing, legitimizing and propagating a simplified image of it." (Saito, 2020, p.1237). However, the exoteric circle also equips the circle of specialists through "basic (linguistic, perceptual, and mental) notions and schemes" (Saito, 2020, p.1240).

In general, an individual belongs to a few esoteric circles and many exoteric ones. This occurs because the EP in a certain esoteric circle is restricted to specialists in the area, which ends up leading to coercive processes; that is, for an individual to belong to this circle, he must specialize in the knowledge socialized in the respective PC (Fleck, 2010). The EP is shared within a given PC through the intra-collective communication of ideas and practices. Oliveira (2012) calls intra-esoteric traffic[2] the instance of intra-collective communication of ideas that occurs within an esoteric circle. It aims to reinforce the particularities of the EP that characterize the respective PC (Fleck, 2010), so that the terms, techniques, and methods are well defined and consensual among its members. The intra-collective communication of ideas from the esoteric to the exoteric circles aims to legitimize the processes and knowledge produced by specialists vis-à-vis the gener-

al population. The intra-collective communication of ideas that is established within the exoteric circle is called intra-exoteric traffic (Oliveira, 2012) and contributes to the crystallization and propagation of popular knowledge (Saito, 2020). Fleck (2010) advocates that popular knowledge in the exoteric circle comes from specialized knowledge produced in the esoteric circle, so that "popular knowledge forms specific public opinion and worldview, thus having a retroactive effect on the specialist" (2010). p. 166). Regardless of the dimension of the intra-collective communication of ideas, it always strengthens the EP.

The socialization of thoughts between different CPs is called inter-collective communication of ideas and practices. The fact that an individual integrates several CPs throughout his life makes him a vehicle for this inter-collective traffic of thought. For Fleck (2010), the inter-collective communication of ideas causes concepts referring to an EP to enter other CPs, so that "any inter-collective traffic of thought brings with it a displacement or an alteration of the values of thought" (p. 161). The closer two CPs are, the more intense the inter-collective communication of ideas and vice versa, so that:

> The thought style of others has an air of mysticism, the questions rejected by him are considered exactly as the most important, the explanations as unproven or erroneous and the problems, often, as unimportant, or meaningless joke. (Fleck, 2010, p. 161).

Fleckian epistemology also predicts that the Science EP can present itself through four social forms of knowledge, namely: the journal science; the handbook science; textbook science and popular science.

The journal science is related to the knowledge shared among the specialists of a CP and involves the most recent works. For this reason, the journal science is characterized by a lack of consensus since it brings inconclusive hypotheses from ongoing research. This knowledge is usually restricted to the esoteric circle, having a provisional, uncertain, fragmented character, but at the same time innovative and directly related to who produced it.

The second form of knowledge is the handbook science. It presents the systematized and consensual knowledge of a given PC. The science of manuals is impersonal and is taken as a reference for the PC, in a way that it exerts coercive and imposing mechanisms, seeking to bring stability to the EP of beginners and directing the training of beginners (Fleck, 2010; Oliveira, 2012).

According to Oliveira (2012) the EP is treated in a more comprehensive and simplified way in the spheres of popular science and textbook science. Popular science is the most basic and broad way of presenting knowledge related to a given PC. It is science socialized in the exoteric circle, directed towards lay people and which supplies most areas of knowledge. The knowledge socialized in the dimension of popular science is given as truths, which can be accepted or denied, but never contested. For Fleck (2010), popular science "presents itself, thanks to simplification, illustrative and apodictic character, in a safe, better-finished and solid way" (p. 166).

According to Fleck (2010), it is not popular science, but the textbook science, that is responsible for introducing science through specific pedagogical methods, but the theorist does not delve into this fourth social form of thought in its constructions.

With these four ways of scaling the EP and the forms of communication of ideas, Fleck (2010) makes evident the social character of science, assuming that for the theory of knowledge, "it is particularly important that the fixed position has a more exoteric character. than that considered more provisional, which is significant for the hegemony of the mass over the elite in the democratic collective of thought" (p. 178-179).

METHODOLOGICAL PROCEDURES FROM THE PERSPECTIVE OF DISCOURSE ANALYSIS

This article stems from a case study qualitative research (Yin, 2001), as it aims to understand a little investigated phenomenon (EF-CERN) from the perspective of the subjects involved with it. Data were col-

lected through semi-structured interviews carried out by videoconference and later transcribed, whose script is presented in the Appendix. In these, the researcher can ask questions that he had not previously prepared or change the course of the interview so that the respondents deepen and detail their answers (Gray, 2012). The interviews lasted between 2 h 40 min and 50 min. Thus, the research corpus consisted of interviews with an intentional sample of six physics professors who participated in two different editions of EF-CERN. The invitation to participate in the research was sent by e-mail to all participants of the different editions of EF-CERN. This invitation was kindly forwarded by the person in charge, together with the Brazilian Society of Physics, by EF-CERN, after the authors of this work had requested it.

According to Zimmermann & Silva (2014) interviews are not conceived only to obtain information, but rather that the conditions of speech production depend on the interviewer, the interviewees, and the context of the interviews. In the case of this work, the interviews are about EF-CERN, however the speeches produced during them can be influenced by the asymmetrical relationship existing between the interviewer and the interviewees, since the former is a researcher in science education linked to a university and these, teachers of basic education. According to Zimmermann & Silva (2014, p. 40-41) "this asymmetry goes back to a historically constructed university-school relationship that has repercussions on the imaginary formations that can preside over the exchange of words between the interlocutors, regarding the positions occupied, now. of the interviews [...]".

Chart 1 presents some characteristics of the research participants.[3]

Chart 1. Profile of research participants

Professor	Experience (years)	Network(s) of action	Highest academic level
Iarley	3	Federal	Master's Degree in Physics Teaching in progress
Paulo César	12	Federal	PhD in progress in Education
Marcos Antônio	10	State and private	Graduation in Physics
Clemer	20	Municipal and state	Master's Degree in Physics Teaching in progress
Rafaela	25	State	Academic Master's in Physics
Fernando	10	Federal	PhD in progress in Education

Professor Fernando was interviewed four years after participating in EF-CERN. His interview was the first to be conducted and served as a pilot study for subsequent ones. However, the relevance of Professor Fernando's answers to the study was significant that it was decided to include his interview in the corpus of analysis. The other teachers were interviewed on two occasions. The first occurred days before the participation of EF-CERN, and the second between thirteen and seventeen months after the participation. As this work is a part of a broader research, the analysis presented here mainly uses transcripts of interviews carried out after the teachers participated in EF-CERN, a reason that reinforces the pertinence of including Professor Fernando as a participant in the research. The few excerpts from the interviews prior to the course are highlighted in the text.

As a theoretical-analytical device, the Discourse Analysis (DA) of Michel Pêcheux's French line was used (Brandão, 2014; Pêcheux, 1997, 2006, 2014; Orlandi, 2008, 2015) which mobilized Fleck's epistemology as the main theoretical framework. The DA of the French line has an epistemological basis constituted by the tripod[4] Linguistics, Historical Materialism and Psychoanalysis. The choice for this field of study is due to the epistemological possibilities of understanding the meaning of the speeches of the teachers who participated in the research. DA implies the articulation of the theoretical device with the analytical one, that is, one of the assumptions of DA is that there is no single meaning in the discourse, and it is the analyst's task to understand the different possibilities of meaning from the dialectical articulation between the theoretical

assumptions methodological. For a better understanding of this proposal, some of the main concepts that are mobilized in this analysis are explained: production conditions, discursive formation, subject-form, subject-position, imaginary formation, and ideological formation.

To understand the meanings of discourse, one of the first aspects to be considered is the conditions of production in which the discourse occurs. This means that, in addition to the linguistic elements, it is necessary to consider the elements of the materiality of reality, which includes considering the socio-historical context in which the discourses are produced (Leandro-Ferreira, 2020). In this sense, every discourse is materially inserted in a historicity and the subject represents a place from which one speaks (Brandão, 2014). Thus, the effects of meaning in the speeches, among their interlocutors, derive from the conditions of production (Pêcheux, 2006). Therefore, the production conditions in this study involve the context of the interviews and are being determined by the detailing of the situation in which EF-CERN occurs, in teacher training, which implies considering the European and Brazilian realities, whose space and historical period are prior to the COVID-19 pandemic. These conditions are inserted in the capitalist social formation, from the production relations that establish a society.

When carrying out a communication, under certain production conditions, an imaginary formation is also considered, which concerns data such as: where one speaks from, who speaks and when does one speak, how one speaks – from an anticipation in the interlocution with the other, that is, an image is produced of what the other should hear and how to listen (Zimmermann & Silva, 2014). Directly or indirectly, power relations are established there depending on the position that the subject occupies and the image he must produce in his speech. In other words, these are established relationships that result from projections, anticipations, that characterize the imaginary formation (Leandro-Ferreira, 2020; Orlandi, 2015).

The representation of the imaginary formation will be inseparably related to the ideological formation (IF). This can be considered when, from the social formation, production conditions and discursive place, the meanings of the discourse point in the direction in which the contradiction arising from the class struggle is evidenced, that is, it implies the defense of different interests and representing antagonistic societal projects. In other words, FI represents the defense of a certain class position based on the social formation in which it is inserted. For Pruinelli (2020) FI can be understood as "a series of sayings, rituals, practices, representations that, according to the current social formation, establish class positions, based on the relationships established between the subjects" (p. 121).). For a better understanding of IF, it is necessary to consider the role of the Ideological State Apparatus (IEA) in this scheme. Such devices, according to Althusser (1999), have the function of guaranteeing "the reproduction of production relations which, at the same time, are relations of exploitation" (p. 225). The result of the action of the AIE is the ideological questioning of the subject, which inevitably occurs from the relations of production of the social formation that is structured.

The IF will be related to certain discursive formations (FD). These are characterized by the hegemonic saying of a group or a class, so that saying represents them. In terms of AD, what can and should be said, under the circumstances in which communication takes place (Brandão, 2014; Pêcheux, 1997), that is, what is said must be aligned with a type of ideology – beliefs, values, practices, recognized knowledge, which are socially shared by those who identify with a given FD. Therefore, the Fleckian EP can be understood, in the light of AD, as a FD.

The DF contemplates one or more subject positions, which does not mean to say that all the sayings of the same DF are consensual or uniform, on the contrary; there is a space for differences, contradictions, divergences. In this sense, the DF is marked by heterogeneity, although it has the subject-form, that instance that ensures the identification and constitution of the DF (what regulates what can or should be said and which was mentioned earlier). This heterogeneity results in the possibility of the existence of different subject-positions in the same DF, which guarantees the movement of saying and the slips of meaning produced in and by the discourse. These basic concepts will be articulated with the research results.

CERN PORTUGUESE LANGUAGE TEACHERS PROGRAMME: LINKS BETWEEN LUDWIK FLECK'S EPISTEMOLOGY AND DISCOURSE ANALYSIS

To understand the meaning effects of discourse, it is necessary to consider its production conditions, which involve two dimensions: the immediate and the broad context (Orlandi, 2015). Regarding the immediate context, it is necessary to highlight that the interviews were about EF-CERN and the discourses produced by the teachers are influenced by historically constructed imaginary formations that refer to power relations between university and school. According to Zimmermann & Silva (2014) these imaginary formations refer to the fact that the school has its social value minimized, since it only reproduces the legitimate knowledge produced at the university. The fact that the interviewer is linked to the university and the interviewees work in basic education can condition the speeches and these aspects must be considered.

Regarding the broader socio-historical context, it is necessary to consider that the object of the discourses of the participants of this research is about the experience at CERN, in Geneva. With this, there is an imaginary formation, resulting from the historical process of colonization of peoples, which predicts that European education, par excellence and by tradition, represents valid science, with greater quality and scientific training. Thus, Europe would be the privileged locus to produce scientific knowledge. It should be noted that CERN, created in 1953, is considered, according to the FCT (2019), one of the most important research laboratories in particle physics today, and its purpose is the "promotion and collaboration between European countries in the area of fundamental research in the field of High Energy Physics (FAE), in order to allow Europe to lead in this field" (s.p.).

This imaginary formation of the domain of scientific knowledge can be identified in the perception of some teachers, before going to CERN, and who demonstrate a relationship between the context and the memory of saying (Orlandi, 2015):

> *[...] It's a person who doesn't know what life outside CERN is, outside the laboratories, [...] They don't know the baker, the butcher (Clemer).*
>
> *[...] the big heads, the 'nobels of life' there, phd to the tenth power (Rafaela).*

The statements above indicate that the imaginary formation of scientists is related to caricatured images of "mad scientists", who dedicate all their time to research and studies, who are alien to the extra-laboratory world. After the experience at EF-CERN, despite the impact of imaginary training on the supremacy of science being maintained, it appears that the participants attenuate the representations of scientists in relation to the interpersonal aspect.

> *We get the impression that they think: – Wow, I'm not going to talk to someone who is less than me. No, there it was very human and very nice of them to answer all the questions we asked (Iarley).*
>
> *[...] people who work with research, well, I think we are going to stay in the background, "to the side", but no! I thought they treated us well [...] (Clemer).*

The discursive clippings highlighted above indicate the possibility of symmetry in the relationship between scientist and professor. This aspect is important, because as advocated by Drayton and Falk (2006) and Grotzer (n.d) horizontal relationships between scientists and teachers during training courses that have this specificity contribute to the establishment of bonds and to the professional development of teachers, although this aspect is not modify, in the case of this research, the imaginary formation of science.

According to Garcia (2015), one of the objectives of EF-CERN is to transform teachers into disseminators of research carried out at CERN. This is explicitly said during the activities, so that in this training there is an ideological reproduction of scientific knowledge, and which is perceived by the teachers who participate in the course:

[...] open the doors for us to get to know their work and for us to be a promoter of what it is to do science, of what is done there. (Rafaela).

[...] to publicize research, CERN and particle physics (Fernando).

Thus, the broad context can make the teacher feel 'privileged' to participate in EF-CERN, which ends up reinforcing the commitment to the organization, carrying out, on return to Brazil, dissemination activities related to CERN. Costa et al (2021) also identified that teachers perceive themselves to be involved and responsible for multiplying their experience at CERN.

Articulating Ludwik Fleck's epistemology with AD to interpret the discourses about EF-CERN produced by the research participants during the interviews, it is recommended that the thought style would characterize the discursive formation in particle physics, in which both teachers and scientists are enrolled. It is the discursive formation that indicates whether an individual can belong to the thought collective, which, in the light of DA, is configured as a subject-form. In this case, the subject-form corresponds to the CP to which scientists and professors, in the context of EF-CERN, belong. DF is subdivided into three subject positions: i) the journal science (related to those that produce knowledge related to particle physics); ii) the textbook science (in which are inscribed those who make use of more simplistic versions of the theories elaborated, presenting a nuanced EP); iii) the handbook science (related to aspects of particle physics that are already consensual and well established).

Scientists, by conducting research and building knowledge in the area, produce meaning effects consistent with the subject-position of journal science and, for this reason, belong to the esoteric circle of the PC. The fact that teachers do not produce scientific knowledge related to particle physics, but appropriate it from the intra-collective communication of ideas, justifies their belonging to the exoteric circle and being inscribed in the subject-position of textbook science. Martins (2020a) has a similar understanding to the above, stating that "physics researchers would be in the esoteric circle and physics teachers in basic education would be located in the exoteric circle" (p. 1200). Finally, because the initial training of both scientists and professors are similar (undergraduate in Physics), both are enrolled in the subject-position of handbook science.

Figure 1 aims to represent the PC established in EF-CERN. The esoteric circle corresponds to the interior of the dotted circle, where EP is mostly linked to the journal science. The darkest regions would be occupied by more experienced scientists, while those closest to the dotted line would be beginners and researchers from similar areas. The physics teachers participating in EF-CERN would be in the region outside the dotted circle, which represents the exoteric circle. In the regions of the exoteric circle adjacent to the dotted circle, there would be teachers with more advanced knowledge in particle physics, while teachers with little knowledge in this area would appear in the lighter regions. The arrows seek to illustrate the intra-collective communication of ideas.

Figure 1. EF-CERN Thought Collective

The understanding that EF-CERN is constituted by a single CP comes from the fact that the knowledge socialized explicitly is only scientific related to particle physics and not pedagogical, although, implicitly, aspects of the nature of science are also shared. If the course provided an opportunity to discuss pedagogical knowledge, possibly teachers and scientists, in certain situations, would belong to different CPs, so that the inter-collective communication of ideas would be established. However, the way EF-CERN is structured, with expository approaches and teachers assuming passive postures, does not allow pedagogical and experiential knowledge to be socialized and discussed.

The absence of a pedagogical approach at EF-CERN is verbalized by Paulo César:

> *[...] I felt that there was a lack of a strong advisory or research team in human sciences, in education itself. [...] A foundation that justifies why it is done this way. [...] A foundation within the science of education is needed that will validate actions or reflect on changes.*

It is noteworthy that Professor Paulo César, at the time of the interview, was doing a doctorate in education and, perhaps, his speech may have been permeated by this situation. When emphasizing scientific knowledge, there is an effect of meaning when there is no concern with pedagogical issues in training, as can be identified in the statement of one of the scientists, during the development of one of the activities of the course:

> *"I'm not here to teach you how to teach particle physics to high school students, because as we teach, we assume that this is already normal for you. We are here to approach particle physics as it is studied at CERN" (Paulo César).*

As they were enrolled in the subject-position of textbook science, teachers expected that aspects related to pedagogical knowledge would be covered, which did not happen in practice. Scientists approach particle physics in the journal science dimension:

> *It was very clear that they call the teacher there to learn and to get in touch with these contents [of particle physics] (Iarley).*
>
> *[...] they [researchers] always made references to what they developed at CERN (Clemer).*
>
> *The researchers weren't worried about taking it to high school. I identified the concern of giving a lecture, but as if it were a formal lecture, without guidance for teachers who work in high school (Fernando).*

So, CERN wanted to work on the development of particle physics with teachers as hard as possible, without worrying about how the teacher would pass it on to high school. There was no didactic question (Paulo César).

The excerpts above show that EF-CERN prioritizes scientific knowledge to the detriment of pedagogical knowledge. Many researchers are more concerned with presenting their research than with whether the approach takes place at the level of teachers' knowledge, and whether the exposed content would be relevant to them. Thus, a subject-position of total identification with the formation of CERN becomes explicit and is linked to an IF of scientific knowledge, independent of pedagogical concerns or its applicability. These aspects reinforce the DF that professors and researchers, in the context of EF-CERN, belong to the same CP, with the communication of ideas of an intra-collective nature, involving mostly scientific knowledge of particle physics.

The creators of EF-CERN seem to have the understanding that the discussion about scientific knowledge about particle physics is enough for teachers to approach them in the classroom. These elements are present in the discursive clipping of professor Paulo César who reproduces the speech of one of the speakers:

We are going to see Particle Physics at the highest level that it has at the level that CERN researchers see so that you can make the deepest update that you have and use all your teacher know-how to adapt to the level of your students. [...] The adequacy to the level they left up to us.

The meaning effect above highlights the production conditions established at EF-CERN. In an anticipation process (Orlandi, 2008), the researcher warns that he will approach the content in the way that it is discussed among scientists who work in one of the largest particle physics laboratories today, stressing those educational aspects will not be discussed, leaving it up to each one, because they are teachers.

Shulman (1987) warns that when teachers do not master a certain content, they have a greater tendency to make use of traditional strategies to teach them, or even omit them. The researcher's belief that it is sufficient to have a knowledge of the content (Shulman, 1987) developed to work with it in the classroom is flawed, and the fact of treating particle physics at the level of journal science can compromise its approach. in secondary education by teachers.

The type of organization and posture of EF-CERN is close to the model of technical rationality (Contreras, 2012). According to the author, this model has a positivist epistemological view, so that the teacher is seen as a professional who relays the knowledge produced by the specialists, without reflection. Thus, Contreras (2012) states that "professional practice consists of the experimental solution of problems through the application of previously available theoretical and technical knowledge, which comes from scientific research" (p. 101). In this sense, there is a disconnect between scientific knowledge and the classroom reality experienced by teachers.

The technicist and positivist DF is reinforced by the non-saying in relation to educational aspects, as moments for reflection and discussion of pedagogical issues that may be involved in the approach to particle physics in basic education are not foreseen at EF-CERN.

"Because we had more moments of Physics training, in the Physics nucleus, so to speak. And how to transform it? Because it is a school for teachers who will have this job later and notions of this have not been worked on much" (Iarley).

Professor Iarley's statement endorses the view that EF-CERN is permeated by a model of technical rationality, which permeates the idea that the discussion of scientific concepts is enough to "instrumentalize" teachers and make them take the contents worked on in the course for the classroom. Wright (2015) already warned that teacher training in which the contents covered are very specific and disconnected from the reality of the classroom, end up being disregarded by teachers. Thus, there is a risk that contents on particle physics are not covered in the classroom, causing teachers to socialize in their classes only more concrete aspects of the experience at CERN.

Furthermore, many of the discursive excerpts reproduced implicitly carry the IF of knowledge, in which the scientist, being linked to research, is not concerned with education. In this scenario, the premise that researchers and professors are enrolled in different subject-positions is reinforced:

[...] because they are not teachers, because they are researchers, right?! (Rafaela).

They just didn't know how to make references to High School [...] It's just that they don't know what High School is, right? (Clemer).

The discursive clippings above are impregnated with an imaginary formation that researchers do not have didactics. Drayton and Falk (2006) warn that tensions between professors and scientists can arise when they use traditional didactic strategies that go against what the former defend. All these aspects can make teachers not work, in the classroom, with the particle physics contents covered at EF-CERN.

THE COMMUNICATION OF IDEAS

The intra-collective communication of ideas between scientists (esoteric circle) and professors (exoteric circle) in the CP of EF-CERN is provided in activities such as seminars and mini-courses given by researchers, technical visits, breaks between one activity and another, moments of collective meals etc.

Generically, intra-collective communications between scientists (within the esoteric circle - intra-esoteric traffic) involves knowledge of the journal science and are established through scientific congresses and publication of articles, seminars, and meetings of research groups. In the case of EF-CERN, intra-esoteric traffic[5] is manifested when scientists attend lectures by other colleagues or make technical visits with professors in laboratories other than those in which they carry out their research.

The intra-collective communications that are established within the exoteric circle (the intra-exoteric traffic), in the case of EF-CERN, take place through the exchange between teachers at different times when they are gathered.[6]

For standardization purposes, the various dimensions of the intra-collective communication of ideas and practices will be written in the following ways: eso-exo communication to designate the socialization between the eso and exoteric circles of the same PC. Intra-esoteric and intra-exoteric traffic will be used to represent interactions between peers of the same circle, that one, between scientists; this, among teachers.

The eso-exo communication

The eso-exo communication of ideas in the context of EF-CERN occurs mainly during technical visits and exhibition seminars, with scientists as protagonists in conducting training. They are responsible for the entire organization of the course, from the presentation of seminars, lectures and mini courses to the follow-up and explanations of technical visits. In contrast, basic education teachers passively attend the course, that is, the subject-position points to an acceptance of knowledge that ideologically represents the dominating power of science. For Olin and Ingerman (2016) and Grotzer (n.d.), this type of structural organization in which teachers are considered passive recipients in training courses can make it difficult to build new knowledge, as well as limit teacher professional development. In other words, it would prevent the possibility of identifying other discursive and ideological formations that represent the exchange of knowledge and the collective construction of knowledge.

In the first days of the EF-CERN program, there were mini-courses and more general seminars, whose contents are close to the science of manuals. On the other hand, science-related content from journals, such as lectures on more specific topics of research developed at CERN and unsolved problems in particle physics, were presented in the last days of EF-CERN.

The mini course on Particle Physics presents the "certainties" of the area, as they are knowledge that have already been systematized and represent the majority thought of the esoteric circle of this area of knowledge. These idiosyncrasies make the content of the mini course at the level of handbook science. For Fleck (2010), this way of thinking has imposing and coercive traits that seek to reinforce the EP, directing the training of teachers. In addition, activities with themes closer to the handbook science, as they present structured, consolidated, and consensual theories of the EP, are easier for teachers to understand, as they had an initial

training in this subject-position. On the other hand, activities predominantly centered on the journal science raised more doubts and difficulties in assimilation, since professors are not enrolled in this subject-position. These discrepancies between the two subject-positions are explicit in the discursive excerpts below and can trigger tensions and highlight power relations between those involved:

> *[...] until the fourth day of the course, I think they were approaching [something that] I was able to develop at the school where I work. On the fifth and sixth days, in the lectures, when they started talking about Feynman's lines, asymmetries, then I think it was way beyond high school (Clemer).*

> *Their perspective (researchers) and their approach consider different assumptions, and these assumptions make [...] in fact they don't know (Fernando).*

In the classroom, teachers socialize scientific knowledge from the subject-position of the textbook science, however, as in undergraduate courses they had contact with the handbook science, they resort to it in a few opportunities. In a similar way, scientists also had contact with the handbook science in their initial training and continue to make use of it at different times. However, in the daily lives of scientists, the most practiced way of thinking is journal science. This corresponds to advanced mathematical and computational methods, going through specific experimental techniques, to mastering jargon and terms specific to the area, in addition to knowledge of open research problems. In this sense, the scientific knowledge socialized at EF-CERN is mostly at the levels of the subject-position of scientists, but not of professors since the intra-collective communication of ideas is developed in the light of the assumptions of the journal and handbook sciences. As a result, teachers are less familiar with the first than with the second, as the former involves specific elements of the EP. This emphasis given at EF-CERN may prevent professors from working with their students on many of the contents taught at the science level of the journals. This aspect is made clear in the excerpt below:

> *[...] several speakers talked about what they do there and its heavy physics content. Everything that is not part of what I work in High School [...] we leave a little aside (Rafaela).*

Part of EF-CERN's schedule of activities involves technical visits, such as trips to data processing centers, control rooms and even accelerators such as the LHC. In these technical visits, the professors are accompanied by the scientists. This is an important moment of the course, because during the visits, the professors identify that in the different sectors of CERN there is a collaborative work between more experienced researchers, graduate students, and technicians. During the visits, there is an entire technical explanation of the functions and particularities of the respective sector. For many research participants, these moments were emblematic during EF-CERN, as expressed by professors Clemer and Rafaela:

> *So, it was the technical visits that I liked the most, the detectors I found the most fantastic part. Because we see it on the computer and sometimes in an image on TV and as much as they comment on the grandeur, when you're close by, that's when you realize it (Clemer).*

> *So, I think everyone will answer that he went down to the cave. Went to see the accelerator, it was cool because we only saw it through the videos (Rafaela).*

As identified by Costa et al. (2021) the teachers participating in this research highlight emotional involvement and sensory experience as a striking element of technical visits. In this sense, the playful aspect of visitation can overlap with the scientific content related to the physical principles of operation of detectors and accelerators, for example. This is possibly because these themes are inscribed in the subject-position of the journal science or because they contain very technical and specific elements of the science of manuals. In a different way, Professor Fernando emphasizes the relevance of these moments for the understanding of the research carried out at CERN, as well as the importance of the visits being led by professionals who work in these establishments:

> *I particularly liked the visits because they were conducted by people who lived in that environment and presented a series of things that I think also contributed a lot to our understanding of the topic, of the research in progress (Fernando).*

The intra-exoteric traffic

Intra-exoteric traffic is understood by Oliveira (2012) as a dimension of the intra-collective communication of ideas that occurs within the exoteric circle that, in the case of EF-CERN, is constituted by teachers who are enrolled in the subject-position of the science of books. didactic. Examples of intra-exoteric traffic are moments of informal conversations between teachers, whether during meals; in traffic between one CERN building and another; with colleagues who shared rooms at the hotel, etc. In general, for visits to CERN facilities, teachers were organized into groups. For the research participants, these moments were insufficient:

> *They make those groups separating, putting us with colleagues from other countries, even so the time of coexistence is very small. [...] I thought there was a lack of interaction with people from other countries, a livelier exchange of experience (Marcos Antônio).*

The last daily activity foreseen in the schedule involved the discussion of questions prepared by the organizers of EF-CERN and distributed to the groups that carried out the technical visits. Although this moment was intended for the discussion of aspects of particle physics addressed in the lectures and technical visits, the teachers ended up using this space to deal with aspects related to the classroom, get to know each other and exchange ideas on how to approach such subjects with the students. Possibly this is what the underlined passage in the previous excerpt by Professor Marcos Antônio refers to. In other words, teachers sought to discuss particle physics also in the dimension of textbook science, looking for elements that would allow for a didactic transposition (Chevallard, 1991):

> *From time to time we would exchange some ideas, at that moment there that the staff organized, from the groups, at the end of each day, to be able to raise the questions [...] Well, that moment ended up being a moment of interaction, but in the rest, the thing ended up being rushed and it didn't make it possible (Fernando).*
>
> *There were some moments when we had to summarize the day. [...] and then some things came out [about the didactic transposition] (Iarley).*
>
> *[...] taking it to high school is something we only do at another time, or we do it in moments of conversation between us (Fernando).*

EF-CERN has Portuguese-speaking professors from three different continents as participants, whose cultural diversity would be a very rich element to be explored. However, there are no formal moments in the EF-CERN program for the presentation of participants, or for discussions about the teaching of physics and the particularities of education in each country. These aspects ended up being explored when teachers met informally:

> *You meet other people from other countries who also speak Portuguese, right? And what we talked about most, incredible as it may seem, was not about CERN, we talked more about the classroom in each country (Clemer).*
>
> *We had notions of what Physics classes are like in Africa with African teachers. I had no idea they had 100 students per class (Iarley).*
>
> *[...] Portuguese teachers have a lot of problem with the salary issue, and they are in crisis and all. So, they also complain about the way teachers are hired [...] that there is no competition (Marcos Antônio).*
>
> *The problems are the same. In the classroom there is a lot of talk, there are few who want to study (Clemer).*

The excerpts above identify more general and curious aspects referring to the specificities of teaching in each country and not more systematic discussions on pedagogical issues. If EF-CERN not only contemplated scientific knowledge, but also pedagogical knowledge, official spaces in the course's program could deepen themes involving the teaching of particle physics in basic education, suggestions for didactic strategies and reports of experiences already carried out by teachers. In addition, conversation circles could be established for teachers to present the reality of teaching in their countries of origin. It is believed that such activities would contribute to the professional development of the teacher, representing another FD, another EP, another CP, a CP related to pedagogical knowledge.

CONCLUSION

In this study, Fleck's epistemology was used to interpret the EF-CERN. Arguments were presented to understand this short course as a single CP, in which the EP of particle physics is shared, which represents the same FD. In this CP, scientists appear in the esoteric circle and physics teachers in the exoteric. Scientific knowledge is socialized via intra-collective communication of ideas and mainly aims to transform the teacher into an ideological promoter of CERN. Pedagogical aspects are neglected at EF-CERN, since there is no relationship between the content covered and high school. The knowledge socialized at EF-CERN is inscribed in the subject-positions of the journal and handbook science. Understanding the journal science requires a more current and specific knowledge of particle physics, consistent with that dealt with within the esoteric circle, and which, in some situations, professors do not have, which is why they often had difficulty in following certain speeches.

The structure of EF-CERN makes teachers assume passive positions during activities and does not allow for issues related to pedagogical knowledge to be discussed and incorporated into training. The level of particle physics discussed at EF-CERN distances itself from daily teaching practice, leading to an approach that is often decontextualized, incomprehensible and irrelevant to teachers, causing them to often disregard them and not incorporate them into their teaching practices.

Many studies have advocated that teacher training should have the knowledge of teachers as a starting point, allowing both content and pedagogical knowledge to be developed (Marcelo, 2009; Loucks-Horsley et al., 2009,). Loucks-Horsley et al. (2009) and Van Driel et al. (2012) also suggest that didactic strategies should be presented that teachers perceive as relevant and that can be used with their students in real classroom situations. In other words, teacher training must also involve teaching experiential knowledge, with their activities centered on the school, being consistent with concrete teaching situations (Marcelo, 2009; Carvalho & Martins, 2018). Teacher education should allow teachers to investigate and reflect on their own practice, focusing on collaborative learning among peers (Van Driel et al., 2012). All these aspects do not seem to support the EF-CERN, which could be an explanation of why teachers, despite superficially approaching some aspects of particle physics in the classroom, do not change their pedagogical practices. Furthermore, according to Van Driel et al. (2012) short-term continuing education (such as EF-CERN) tends to be less effective than long-term proposals.Assim, amparado em Zeichner (1993), Schön (2009) e Carvalho & Martins (2018), alvitra-se que o fato da EF-CERN possuir uma abordagem instrumental baseada em conhecimentos de conteúdo que valorizam a competência técnica dos professores, distantes da realidade da sala de aula e não pautada na reflexão sobre a ação e no professor como pesquisador de sua própria prática, obstaculizam o desenvolvimento profissional docente.

However, it is undeniable that visiting one of the most important physics research centers in the world, traveling to Europe and having contact with scientists, other cultures and customs is a unique experience for many EF-CERN participants. Thus, this experience can deeply mark the teacher's life experiences. As recommended by Marcelo (2009), the teacher's life experiences, beliefs and values also influence his construction of teaching identity, in this case, he enthusiastically reports the experience at CERN and the research carried out there, becoming a popularizer. of the research center.

Furthermore, the experience at CERN, especially the technical visits and the interaction with the scientists, helps the professors to develop a less caricatured view of scientific work, building more desirable conceptions of the nature of science.

For these reasons, it appears that the activities carried out by the teachers participating in EF-CERN are limited to scientific dissemination, concrete aspects of the trip and a superficial approach to particle physics. An in-depth discussion of aspects of particle physics and changes in its teaching practice are not verified.

As a suggestion, EF-CERN could have a structure that favors the inter-collective communication of ideas, as they are the ones that contribute to changes in the EP. In this sense, EF-CERN could be constituted

by a CP of physics (in which scientists would be in the esoteric circle); a CP of pedagogical knowledge (having trainers and researchers in science education in the esoteric circle) and a CP of experiential knowledge (having the teachers of basic education themselves in the esoteric circle). Activities that provide horizontal relationships between these three groups, valuing the different types of knowledge, could help teachers to advance in their professional teaching development. Perhaps part of the training at EF-CERN could also take place in Brazil, with researchers from different areas of knowledge involved, increasing the duration of training. Regardless of the form, the relevance of constituting a training space that, in addition to scientific knowledge, provides the opportunity for the communication of pedagogical knowledge and experiential knowledge, through collaborative actions between peers and with activities that relate to concrete situations experienced by the student, is highlighted. teacher at school, allowing him to reflect on his own practice.

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NOTAS

1 Refers to the period in which activities and exchanges were face-to-face, at CERN's facilities in Geneva. After 2019, due to the global health crisis resulting from the Covid-19 pandemic, face-to-face activities we suspended.

2 The expressions 'intra-esoteric traffic' and 'intra-exoteric traffic' are denominations used by Oliveira (2012) and are not included in the original work by Fleck (2010).

3 For ethical reasons, teachers will be identified with the following pseudonyms: Clemer, Marcos Antônio, Paulo César, Iarley, Rafaela and Fernando. The non-reference to the year in which they participated in EF-CERN is deliberate, so that their identities are preserved.

4 From Linguistics, the change in the object of analysis is extracted, shifting it from the textual domain to that of discourse; from Historical Materialism, the dialectical vision and the concept of ideology stand out; in turn, the issues of the construction of the subject from the other and the unconscious come from psychoanalysis (Orlandi, 2015). It is based on the articulation of these three areas of knowledge that Michel Pêcheux's DA epistemology is constituted.

5 It was not the aim of this research to investigate intra-esoteric traffic. However, we believe to be an interesting research problem for future investigations.

6 This dimension of the intra-collective communication of ideas is detailed in subsection 4.1.2, aware that Fleck rarely discusses it in his works (Oliveira, 2012).

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APPENDIX

SCRIPT OF SEMI-STRUCTURED INTERVIEWS CARRIED OUT WITH TEACHERS AFTER PARTICIPATION IN THE CERN PORTUGUESE LANGUAGE TEACHERS PROGRAM

1. Explore what the CERN experience was like.
2. What impressed you the most at the CERN Portuguese Language Teachers Program?
3. Explore perceptions about the program offered by the CERN Portuguese Language Teachers Program.
4. About the theoretical level (and adequacy to the school reality) of the courses and lectures, what did you think?
5. What are the positives and negatives points of your experience in Geneva?
6. Do you have suggestions for future editions? What did you miss?
7. Explore how the interaction with the other teachers was.
8. Explore how the interaction with the scientists was.
9. How does a scientist work?
10. How is science done?
11. Has your idea of a scientist matched with the one you found at CERN?
12. Comment on the before, during and after going to CERN at your school (involvement with students, colleagues, community, etc.).
13. How are your classes? What changed on your return?
14. Request examples of activities developed related to the CERN Portuguese Language Teachers Program.
15. What CERN outreach activities have you done or do you intend to do?
16. Do you feel able to work on particle physics in high school? Explore
17. Explore aspects related to modern and contemporary physics.
18. What are your professional plans for the future? (Look for CERN influences on this).