

# Pedagogical Content Knowledge In University Teaching: Discourse Analysis Of Physics Teachers<sup>1</sup>

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## ABSTRACT

This research aims to identify the Pedagogical Content Knowledge of four university Physics professors at a public university in Rio de Janeiro, based on their speeches about their practices. It is understood that in Higher Education there are several criticisms regarding the practices and pedagogy of teachers who did not have training correlating pedagogical knowledge to content knowledge. The research was based on references linked to Teaching Knowledge and PCK and on the Bakhtinian reference for Discourse Analysis, defending that social interactions influence the statements of each subject. Among the results, it is possible to note the importance of mastering specific knowledge in pedagogical strategies for a more critical and reflective teaching, breaking with an education that aims purely at the transmission of content, without concern for the sociocultural context.

**KEYWORDS:** Pedagogical Content Knowledge. Dialogic Discourse Analysis. University Teaching.

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*Conhecimento Pedagógico do Conteúdo na Docência Universitária:  
Análise de Discurso de Professores de Física*

**RESUMO**

Esta pesquisa tem por objetivo identificar o Conhecimento Pedagógico do Conteúdo de quatro docentes universitários de Física de uma Universidade pública do Rio de Janeiro a partir de seus discursos sobre as práticas. Entende-se que na Educação Superior há diversas críticas em relação às práticas e à pedagogia dos professores que não tiveram formação que relacionasse conhecimentos pedagógicos aos conhecimentos do conteúdo. A pesquisa contou com referenciais ligados aos Saberes Docentes e ao PCK e com o referencial bakhtiniano para a Análise de Discurso, defendendo que as interações sociais influenciam os enunciados dos sujeitos. Dentre os resultados, nota-se a importância do domínio de conhecimentos específicos em estratégias pedagógicas para um ensino mais crítico e reflexivo, rompendo com uma educação que vise puramente transmissão de conteúdos, sem preocupação com o contexto sociocultural.

**PALAVRAS-CHAVE:** Conhecimento Pedagógico do Conteúdo. Análise Dialógica do Discurso. Docência Universitária.

*Conocimiento de contenido pedagógico en la docencia universitaria:  
análisis del discurso de profesores de física*

**RESUMEN**

Esta investigación tiene como objetivo identificar el Conocimiento del Contenido Pedagógico de cuatro profesores universitarios de Física de una universidad pública de Río de Janeiro a partir de sus discursos sobre sus prácticas. Se entiende que en la Educación Superior existen varias críticas en cuanto a las prácticas y la pedagogía de los docentes que no tuvieron una formación que relacionara el saber pedagógico con el saber del contenido. La investigación de contorno con referentes vinculados a la Enseñanza del Conocimiento y CPC y con el referente bakhtiniano para el Análisis del Discurso, defendiendo que los influenciados socialmente influyen en los enunciados de cada sujeto. Entre los resultados, se destaca la importancia del dominio de saberes específicos en estrategias pedagógicas para una enseñanza más crítica y reflexiva, rompiendo con

una educación que apunta puramente a la transmisión de contenidos, sin preocupación por el contexto sociocultural.

**PALABRAS CLAVE:** Conocimiento pedagógico del contenido. Análisis Dialógico del Discurso. Docencia Universitaria.

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## Introduction

The pedagogical training of university professors has been an important discussion topic over the last few decades, especially regarding teaching practices, evaluative methods and the pedagogy of higher education (Silva; Aguiar, 2017). According to Masetto (2003), even though it is important for professors to be qualified, they frequently do not possess the necessary pedagogical skills. Thus, the education of university professors is mainly based on their field of education, not including pedagogical training.

University professors must have solid pedagogical training, aiming to promote learning that generates meanings for the discussion of specific knowledge from each field of study. This stems from the premise that the pedagogical training of university professors can contribute to improving the quality of higher education and to developing innovative pedagogical practices.

In the context of Graduate education, Almeida and Pimenta reveal that:

Studies in the field demonstrate that the preparation of educators for academic life, such as specialists in a specific field of knowledge, mainly happens in *stricto sensu* graduate programs, in which future professors develop the theoretical and instrumental knowledge of the activity of research and consolidate appropriations referring to their scientific field of action. However, their

pedagogical training is practically non-existent in graduate programs (Almeida; Pimenta, 2014, p. 11, our translation)

As a consequence of this almost inexistent pedagogical training, Chauí (2003) argues that the recruitment of professors is conducted without considering their knowledge regarding the course and the relations between it and other similar courses and characterizes university teaching as a process that involves two marks: transmission and training, as well as a process that no longer contains its essential mark: education.

It is known that universities play a fundamental role in society, acting as one of the pillars of formal education to this day. However, there currently appears to be a sort of “fastfoodization” (Debry; Leclercq; Boxus, 1998) underway. The dominance of technician teaching in universities has led to a course organization similar to what one would find in a supermarket, in which students choose the courses available on the shelves, in accordance with the individual decisions of professors or departments. This approach prioritizes the academic career of professors to the detriment of student education, which increases the distance between academic culture and the younger college students. This model generates debates regarding the general education of students for living in society since, according to Zabalza (2004):

It is necessary to insist to the point of exhaustion that an education must serve to qualify people, that is, it is not enough to equip them with a standard professional profile or a certain baggage of knowledge. (Zabalza, 2004, p. 25)

Considering this scenario, in which the preoccupation regarding educational practice in higher education remains current, and based on the criticism presented above, this article’s objects of study are the discourses of four university professors, with the goal of answering the following question: In which manner does pedagogical content knowledge appear in the discourse of university professors? Based on the subjects’ discourses, we seek to identify

and analyze teaching knowledge, more specifically, the pedagogical content knowledge of themes they favor.

The reference chosen for the discourse analysis was Bakhtin, based on the concepts of discourse and statement genres. Our choice of Bakhtin (2006) has to do with the understanding of language, based on the verbal interaction between individuals, as a social and historical process. Language is not understood as a simple tool for communication but also as an activity that involves social interaction and the construction of meanings, an activity that occurs within a specific historical and cultural context and that is influenced by the social, political, and economic conditions present in this context.

### **Teaching knowledge and Base of Knowledge**

Teaching knowledge refers to the set of knowledge, skills and attitudes needed for a professor to do their job efficaciously. This knowledge involves both the knowledge that is specific to the subject the professor teaches and the teaching and evaluation strategies used to teach said knowledge to the students.

Teaching knowledge exists in various formats and, to Tardif (2000, 2002), is characterized as heterogeneous knowledge, which is plural and temporal, as well as social, since its objects (students) are social objects and, consequently, there are plural realities which have different requirements in each situation. Thus, professors are always in the process of learning, taking on the role of students and using classroom experiences to form a part of their knowledge.

The professors' knowledge refers to a type of knowledge that is more fluid and less structured, based on their practices, experiences and achievements throughout their professional performance. While this knowledge is a set of social practices that influence daily perceptions and activities in the educational field, knowledge is a systematic and historical compilation of scientific productions that are submitted to validation rules

and are broadly accepted by the academic community. The base of knowledge, thus, is the set of notions, concepts and theories that substantiate teaching work. This base includes both specific knowledge pertaining to the subject and pedagogical knowledge; that is, the teaching theories and methods that the professors use in the classroom. The base of knowledge further includes knowledge about the context in which teaching occurs, as well as the characteristics of students and educational institutions in which the professors work.

To deal with the concepts mentioned above, the main references used herein will be Tardif (2000, 2002) and Shulman (1986, 1987). Table 1 presents each of said researchers' knowledge and ideas. It is worth remembering that the analyses herein will be geared specifically towards pedagogical content knowledge. However, a general understanding of the knowledge is vital for the discussions conducted during the analyses.

**CHART 1:** Teaching knowledge and Base of Knowledge.

Tardif (2002)	Shulman (1987)
Of Professional Training	Content knowledge
	General Pedagogical Knowledge
Curricular	Pedagogical Content Knowledge
	Curricular Knowledge
Experiential	Knowledge of Students and their Characteristics
	Knowledge of Educational Contexts
Disciplinary	Knowledge of educational objectives, finalities and values, and of their philosophical and historical bases.

**Source:** Created by the authors.

According to Tardif (2002), teaching knowledge includes: Of professional training: set of skills transmitted by teacher training institutions; Disciplinary: social knowledge defined and selected by the university and transmitted in the university's courses and departments regardless of the colleges of Education; Curricular: associated with the discourses, objectives,

contents and methods of the educational institution; Experiential: linked to professors' daily work and their knowledge of their environment.

To Shulman (1986; 1987), the knowledge is divided into: Content knowledge: content to be taught; General Pedagogical Knowledge: linked to the use of pedagogical strategies, overcoming the limits of Content Knowledge to achieve broader objectives; Curricular Knowledge: refers to the knowledge to create programs; Pedagogical Content Knowledge: has to do with the pedagogization of content and will be further discussed in this study; Knowledge of Students and their Characteristics: involves recognizing the individuality present in the educational environment and how it interferes in practices; Knowledge of Educational Contexts: involves an understanding of the classroom, the educational space and institutions; Knowledge of educational objectives, finalities and values, and of their philosophical and historical bases: tied to the understanding of the objectives, values and finalities that guide teaching.

Both authors understand teaching practices and pedagogical theory, supposedly learned at an undergraduate level, as being essential for educator development. Thus, teaching practices are also constituted by pedagogical knowledge, and it is not possible to understand the teaching profession solely through a curricular and titles evaluation. It worth emphasizing that, in the admission process for professors at public and private universities throughout Brazil, special attention is paid to specific content knowledges and to academic titles.

In this article, there will be an emphasis on Shulman's Pedagogical Content Knowledge (PCK), since part of the university professors possess bachelor's degrees that did not require a licentiate degree (degree for those who wish to teach). It is also important to consider that most of the professors did not have access to pedagogical training courses due to the curricula of their bachelor's degree programs.

Pedagogical Content Knowledge (PCK) is a type of knowledge that concentrates on how a professor can teach a certain content. It is formed by

the combination of knowledge regarding the content to be taught with the understanding of pedagogical practices that are adequate for the students. Thus, PCK is not limited to a deep knowledge of content but includes the capability to make it relevant and understandable for students, identifying key concepts, choosing efficacious teaching strategies, using pertinent examples and analogies and adjusting the teaching approach according to their students' contexts. As such, only having knowledge about the content to be taught is not sufficient to guarantee an efficacious pedagogical practice.

The discussion on PCK in higher education teaching is important since it can contribute to the development and to a deeper comprehension of specific contents and to the identification of adequate strategies for teaching them to students in a significant and competent manner. Furthermore, PCK allows professors to make connections between course contents and the pedagogical aspects of teaching. It is vital to know how to adjust the content to different levels of student comprehension and how to deal with the students' previous conceptions that can interfere with learning.

## **Methodology**

To achieve the planned goals, this study followed a path similar to that of the "case study" which, for Yin (2001), is an adequate method for situations in which researchers have no control over the subjects and objects they wish to study. The case that was analyzed involves four professors from the same institution and the objects were their discourses about their practices and knowledge.

It is understood that, when dealing with subjects, there are countless variables relating to both the subjects and the researchers, since the research process involves subjectivity. Thus, the analysis becomes complex, and it is necessary to view the subjects as historical and their discourses as dated and concrete, marked by a culture that creates ideas and awareness. Upon



producing and reproducing social reality, they are also produced and reproduced by the same reality (Freitas, 1996).

The perspective of the socio-historical character, whose Bakhtinian reference is associated, allows for a deeper analysis based on the search for understanding social and historical phenomena in a broader and more complex context with social, political and cultural factors involved in social relations.

The data collection consisted of semi structured interviews with the application of CoRe – Content Representation, a technique that involves the identification and categorization of central themes and concepts present in a dataset, to represent the content in the most accessible and organized manner possible, as shown in Table 2.

**CHART 2: CoRe Instrument.**

	Conteúdo específico			
	Ideias/ Conceitos Centrais relacionados a esse conteúdo			
	Ideia I	Ideia II	Ideia III	Etc
1. O que você pretende que os alunos aprendam sobre esta ideia?				
2. Por que é importante para os alunos aprender esta ideia?				
3. O que mais você sabe sobre esta ideia?				
4. Quais são as dificuldades e limitações ligadas ao ensino desta ideia?				
5. Que conhecimento sobre o pensamento dos alunos tem influência no seu ensino sobre esta ideia?				
6. Que outros fatores influem no ensino dessa ideia?				
7. Que procedimentos/ estratégias você emprega para que os alunos se comprometam com essa ideia?				
8. Que maneiras específicas você utiliza para avaliar a compreensão ou a confusão dos alunos sobre esta ideia?				

Source: Loughran, Mulhall and Berry (2004).

CoRe works based on the selection of a Big Idea from the subject's area of knowledge and based on this theme, ideas that the educator considers important within the chosen subject are selected.

### Data Analysis References

The discourse analysis of the answers given by the four interviewed professors was conducted based on the transcription of their statements.

Excerpts that explain certain types of knowledge and skills were highlighted based on the answers that were given to the questions. The interviewed professors agreed that the data could be shared, as long as it happened anonymously, which led to the use of pseudonyms to differentiate between them. The study was approved by the Ethics Committee, in Ethical Appreciation Certificate no. 64391122.4.0000.5282.

The treatment of the data obtained through CoRe and the conducted interviews was conducted through Discourse Analysis with a focus on Bakhtinian concepts; that is, with Dialogic Discourse Analysis (DDA) as a theoretical-methodological reference. Said concepts are those of discourse and statement genre. Our choice of Bakhtin (2006) views language as a social and historical process of verbal interaction among individuals. Language is not seen as a mere tool for communicating information, but as an activity that includes social interaction and the construction of meaning. Language is also not a monologue, but a dialogue that involves the exchange of different voices and perspectives. Bakhtin understands language as an activity that is developed in a specific historical and cultural context, that is influenced by the social, political and economic conditions present in said context.

Thus, the choice of Bakhtin as a reference occurred due to the possibility of conducting an analysis that is deeper and more coherent with the discourse production context of the Physics undergraduate professors who work in different fields. To Bakhtin, language is composed of ideological signs and its historical character is vital for understanding its nucleus: social interaction through statements. As such, discourse is linguistically structured and, at the same time, constructs meanings in movement, in the statement game, linguistic and translinguistic (Paula, 2013).

The extralinguistic character of language admitted by Bakhtin is vital to understand language, since language exists and evolves historically in concrete verbal communication, and not in the abstract linguistic system of language forms or in the individual psychism of speakers (BAKHTIN, 2006). Language is thus formed by its linguistic structure and by its social and

historical context, with social interactions being modified over time through these processes.

Verbal interactions through enunciation are the true substance of language and the statements produced in interactions do not appear individually, being part of a chain of speech acts.

Every statement, even in the immobilized form of writing, is an answer to something and is constructed as such. [...] Every inscription prolongs those that preceded it, creates a controversy about them, counts on the active reactions of understanding, anticipates them (Bakhtin, 2006 p. 99, our translation).

Thus, statements are the basic unit of communication, they are verbal expressions produced in a certain social and historical context with a specific meaning for those who participate in this context. A statement is not only a sequence of words or sentences, but a unit of sense that is created through social interaction (Bakhtin, 1997).

The collected responses reflect previous discourses witnessed by the professors throughout their lives and in specific contexts. These answers vary for each research subject, resulting in individual analyses. It is important to note that when we consider a statement as a discourse and social unit that generates an answer on the part of the subject, it is crucial to understand that every statement is produced with a communicative intent towards someone. This directionality is based on discursive genres, as outlined by Bakhtin (1997).

According to Bakhtin (1997), the genres of discourse result in relatively stable standard forms of a statement that are historically determined. The author demonstrates that we only communicate through genres of discourse and that subjects possess a considerable repertoire, since even in the most informal conversation there is discourse modeling. Thus, different social situations create different genres, with their particular characteristics.

Despite there being two different data collection instruments, the interview and CoRe, the CoRe data was collected immediately after the interview and, thus, the statements were marked considering the subjects' own alternance, which led to a single transcription for each professor. Each transcription contains both the data collected during the interview and the data collected through the CoRe. In the results analysis, we cited the statements that we considered the most important for the study and, below the excerpts, we conducted the analyses.

## Results

### 1 – Professor 1 and Quantum Mechanics

Professor 1 works with high-energy physics but has had various jobs during his career. From “Van shouter” to university professor, the professor demonstrates through various statements the influence of many voices – world views – that affect his practices (Bakhtin, 2010) and his awareness (Bakhtin, 2006).

60 – I see a group. I had good professors, who ended up influencing me. Concerning the negative aspects as well, there are certain things that I experienced in the classroom as a student that I do not want to reproduce. So I try to watch myself in this sense, right? [2 seconds]. I try not to hide this reflection, which is necessary. And it's something that is “updatable”, right, sometimes things that are interesting today are not interesting tomorrow or vice-versa, so you need to always have this sort of reflection. Sometimes, even colleagues from the Institute with whom I've never had class, but who I see teaching from the hallway and see their boards and I think “wow, what's this... and as an independent student at the time I thought about doing things more like this (this way)”.

At some moments, Professor 1 mentions that he seeks to use what he has already experienced as a student and adjust it to create a less traditional approach in the classroom, thus developing his teaching activities through practices experienced as a student and as a professor. Furthermore, he seeks to break with traditional evaluation methods and uses a “workbench” assessment, believing that constructing an experiment, as well as collecting and analyzing the data, contributes to the teaching-learning process efficaciously.

For this analysis, we presented excerpts from the CoRe instrument and the interview. In the CoRe instrument, the professor selected “Modern Physics” as the big idea and “breaking the paradigm of Classic Mechanics and Quantum Mechanics” as the idea. Professor 1 describes this idea as being the change from the “Macro” world to the “Micro” one and vice-versa.

He further reveals that the “Crookes Tube” experiment is always conducted in class with the students who have just entered the university. This experiment consists of a closed glass tube with low pressure on the inside, a screen and it is connected to high-tension currents. Upon connection to this tension, with the cathode being one of the tube’s extremities and the anode being the other one, the so-called “Cathode Rays” cross the tube, originating from the cathode. These rays are electron beams and are projected around the screen, creating a green light. The Crookes Tube’s functioning involves the application of a high voltage current to the electrons within the tube, creating an electrical field that is strong enough to ionize the gas inside the tube. The electrons that are released by the ionized gas travel through the tube, colliding with other gas molecules and releasing photons, which are the source of the light emitted by the tube. The light emitted by the tube is specific to the gas that is being used and its color can vary, depending on the gas pressure inside the tube. The Crookes Tube was an important scientific advancement and contributed to the development of modern Physics.

**FIGURE 1:** Crookes Tube in the University's Physics Lab.



**Source:** Created by the authors.

Upon mentioning the experiment, the professor indicates the use of paths to present the contents based on the valorization of experimentation in Physics teaching. In statement 68 of the interview, in which he presents the idea used in the CoRe, the professor says:

68 – First... the change from what would be “macro” to “micro”. We need to overcome this barrier. This is the first big idea, we leave a Physics that you yourself characterized as “concrete”, right, we go from Newtonian Mechanics to a sort of Quantum Mechanics that really is abstract. Then we need to contextualize... and one of the forms I really like to contextualize are the observables from this Modern Physics. So if you think we’re going to say... the electron, for instance, there’s that ‘game’ we play when we conduct the load x mass experiment... a student asks “is the electron green, professor?”. We know it’s not green, but the student is building on the thought. So you play around, of course, and so... no, it’s not green, but is it an electron? If you think of an electron’s dimensions, how can you access this scale? This scale goes from [inaudible] from the “macro” viewpoint, you can, through the difference in potential, through the magnetic current field... you can “access this electron”. This is something I think is so cool within this big idea that is Modern Physics. I mentioned the electron, but there are many other questions, right... Planck’s constant, 10 elevated to the  $-34^{\text{th}}$  power,

it's absurd... So how can you reach this scale, how can you (...). From that, you realize that today's world wouldn't exist without this "micro" world. Since... I don't know, you are recording me here with a cellphone, it's absurd... and Modern Physics, this necessary transposition, this break in paradigm, really accesses the invisible world, and you need to go and use Physics in this invisible world, which reflects on the "macro" world you are viewing.

It is well-known that Professor 1 worries about teaching contents in a manner that his students can understand. By presenting contextualization as a strategy: "... and one of the forms I really like to contextualize are the observables from this Modern Physics", the professor presents contents that are considered abstract and are a part of the Macro world, as he himself states. It is possible to say that the professor concerns himself with didacticizing the content, just as he takes care to use examples from daily life that help to explain classroom content, such as the cellphone that was being used to record the interview.

Thus, besides the presence of Pedagogical Content Knowledge in his statement, there is also a reflection about his own practice and awareness of the need to contextualize knowledge.

Professor 1 also comments on the change from Newtonian Mechanics, which are mentioned as being concrete, to Quantum Mechanics, which are considered more abstract. The transition from Newtonian Mechanics to Quantum Mechanics was a complex process, boosted by scientific and experimental advances between the end of the 19<sup>th</sup> century and the beginning of the 20<sup>th</sup> century. Newtonian Mechanics, which were formulated by Isaac Newton in the 17<sup>th</sup> century, described the movement of macroscopic bodies according to precise, deterministic laws. However, with the development of experimental Physics and new phenomena that could not be adequately explained by Newtonian Mechanics, theories and concepts arose that led to the creation of Quantum Mechanics, such as dark matter radiation,

photoelectric effect, Bohr's atomic model and Heisenberg's uncertainty principle.

## 2 – Professor 2 and Entropy

Professor 2 works in Education and, throughout the interview, she demonstrated a constant process of building her image as an educator, with her practice being based on experiences in museums and in basic and higher education. Upon understanding that these experiences and the construction of meanings were fruits of worldviews expressed to her, the professor recognizes the importance of external influences on the development of her own worldview (Bakhtin, 2006). Additionally, she tries to use alternative forms of evaluating student knowledge, partially breaking away from the traditionally analytical evaluation type that is used in a Physics undergraduate program.

During the CoRe application, the big idea chosen by Professor 2 was thermodynamics and the idea she brought up was Entropy which, as she stated many times, is erroneously disseminated as the “degree of molecule disorder”. Throughout the CoRe application, Professor 2 demonstrated knowledge about the concept and the students' alternative concepts. According to her, her students tend to believe this definition due to theoretical divergences with the field of Chemistry, both in basic education and at the undergraduate level, in which the professor defines Entropy as such. To avoid this problem, Professor 2 tries to encourage the students to look for examples in daily life through internet videos, academic articles or even through a low-cost experiment that, according to her, demonstrates the differences between Macrostate and Microstate very clearly, as well as Reversible and Irreversible Processes. Her main object, as she states in excerpts 100 and 102, is to develop a stronger critical sense in her students regarding scientific knowledge. Excerpt 100 answers the question “What do you intend students to learn about this idea?” and 102 answers “Why is it interesting for students to learn about this idea?”:



100 – It is the main thing, because it is a seldom-explored content in Basic Education and even at the undergraduate level... and it has a lot of theoretical divergence with Chemistry, for example. So it is common for you to open books and open videos online... and find “Entropy is the degree of molecule disorder”. And it is not. So my main goal with this content is for students to understand that entropy is not the degree of molecule disorder... that’s the premise, it begins there.

102 – So you start to see that there are other possibilities, right, where we work with Entropy as a variable of State, which is... it can be like this, it can be like that [gesture representation]. So there is this notion of change, and I think that this is very good for Physics teaching, when you go from something that is, that is cemented in place as Classic Physics... so “ah, it is always like this...” the students love this sentence... and it will always be that way, despite one thing or another.  $F$  will equal “ $m.a$ ”. And Entropy destroys this base. “So, there’s something more than this”, there are a thousand possibilities. I think that this change from what “is” to what “is now”, for those who like it, for those who are here taking the course and liked the content, opens a door that makes you want to learn more, because then they will start to ask “Ah, when something happens in the Universe the liquid effect of Entropy increases”: “What do you mean by universe?” Then they start to ask questions about science, about the origins of the universe.

Professor 2 seeks to highlight an attempt to introduce the concept of Entropy as a stimulus for problematizing models and the view of science as cumulative. When she proposes questioning the immutability of the concepts seen in the classroom, she makes it possible for students to develop critical awareness. It is possible to infer, from the professor’s discourse, that she attempts to bring the concept of entropy closer to ideas such as, for instance,

what happens in the Universe, demonstrating mastery over the so-called pedagogical content knowledge.

After these questions, the professor was asked about how students' previous knowledge affects her teaching methods and, in her answer, it is possible to observe a conviction regarding the students' confusion concerning the theory of Entropy as well as analytical and applied development. In her discourse, there is a clear concern regarding content shared online and an attempt to correct some of these materials to use them in class later on or even just for scientific dissemination. Another important aspect is the attempt to organize topic presentation to make student learning easier, which pertains to the skills of selecting and preparing course content and planning the teaching-learning process, from Zabalza (2006). When the professor attempts to make students learn the concept of Entropy, she inverts the course's syllabus to introduce the key-concepts in the beginning, permitting a deeper exploration of the theory in the classroom.

108 – Instead of beginning with “normal”, because here we start with hydrostatics, hydrodynamics, oscillators, waves, sound waves and then we go into thermodynamics. So I am going to invert it. I will put thermodynamics first so that we can start to discuss this concept of energy earlier.

The professor demonstrates her knowledge of the course content, which allows her to understand the nature and the concepts tied to entropy. It is worth noting that this knowledge was, according to her, constructed from the need to understand the content better and find information pertaining to it. Furthermore, she exhibits pedagogical content knowledge when she seeks clearer and more precise alternatives to explain the concept. She recognizes that scientific definitions and concepts are not immutable or absolute but are subject to change and improvements when new evidence and viewpoints enter the debate. With this, the professor appears to stimulate the curiosity and

critical thinking of the students, who can understand science as a dynamic process.

### 3 – Professor 3 and Fiber Optics

Professor 3 is a professor who develops his research in the field of Fiber Optics and Sensors. He believes that his teaching knowledge was developed through practice, reporting that the courses in Education did not affect his trajectory or the construction of his teaching identity. He further reveals that he believes there is a sort of “common sense” in his practice when listening to student criticism regarding the methods he uses. The professor also seeks to, through “common sense”, reproduce attitudes that he considered good and repress bad attitudes experienced during his undergraduate studies. Thus, it is possible to note the influence of his experiences as a student, demonstrating the creation of meaning and awareness through social and cultural impacts around him (Bakhtin, 1997).

Professor 3 makes an important statement regarding the structure of the “Optics” course he teaches, which is offered in the fifth semester of the Physics undergraduate program. According to him, the syllabus ends with optical phenomena that, historically, were discussed at the beginning of the 19<sup>th</sup> century. To him, it makes no sense for the course not to discuss more current topics with a better contextualization. Considering this, he always seeks to bring up more modern topics, such as “Lasers”, arguing that, despite it being 2022 (at the time of the interview) and “Lasers” being a part of the 1960s, there are still examples and applications in daily life, such as microwave ovens and CD and DVD readers. He also mentions LEDs in homes as a more current topic. According to Professor 3, his method attempts to bring the content to a world that is more tangible for students. Thus, it is possible to observe the presence of a preoccupation with content comprehension and a search for manners of presenting the concepts seen in the classroom and bringing them closer to the students and their daily lives, demonstrating Pedagogical Content Knowledge.

98 – It is a new line that, for now, I'm still following on my own. Yes... I try, within what's possible, to teach interactive lessons, like, trying to take... I take experiments, fibers, equipment, videos. If possible, when it's an elective course with fewer students, I speak with my advisor, take the students to a place with better structure to do this... I try to motivate them through practical activities... to have class seeing the thing, if not happening, at least having some of the elements right there to look at "oh, cool".

Professor 3 answered about the strategies he uses to get students to commit to the idea discussed in the CoRe, in which the big idea he chose was "Fiber Optics" and the idea was "Sensors". He commented that the laboratory structures frequently do not permit work on more current or experimental concepts. It is possible to observe that, by attempting to advance historically in relation to the previously mentioned syllabus, the professor is seeking out non-traditional alternatives by bringing equipment and new technologies into the classroom. When possible, he even attempts to conduct visitations to other formal education spaces, more specifically to a laboratory in another university in the state of Rio de Janeiro, as an attempt to bring the students closer to the content taught in the classroom through practical activities. It is possible to identify the professor's efforts to bring the content closer to the observable world, which can be seen as a strategy to facilitate his students' understanding about certain concepts.

Regarding the use of the CoRe, by presenting an optical fiber to the interviewer, the professor demonstrates his efforts to bring the knowledge closer to the students. This happens, as previously mentioned, due to the non-universality of understanding about Fiber optics and Sensors.

Throughout the entire interview, the professor demonstrated his mastery of this idea, which is a part of his field of research, exemplifying the implantation possibilities of these sensors in different fields of knowledge and society through different applications. Alongside these examples, he exhibited

the use of didactical language to explain the content to the interviewer. In statements 88 and 90, Professor 3 answers the questions “What do you intend for students to learn about this idea, about sensors?” and “Why is it important for students to learn about this idea?”, respectively:

88 – In research, even as a motivating element, I try to use examples from a person’s daily life. For instance, I don’t work with... I don’t know, oil duct sensing. So where will I work with that? My last projects have been about milk fraud investigation. Someone goes to the supermarket to buy milk and he might be drinking milk from a brand that tampers with the product. So as a motivational element, specifically concerning this milk issue, for instance: in 2015 there was an operation and now this year there was another one, so we’ll say that from the “main” expensive brands of milk, only one of them had no traces of formaldehyde. These big brands, super globalized food conglomerates, they all exhibited traces of formaldehyde. So how can we investigate that? One way is using, for instance, optical fibers... modifying the fiber, right, and the students learn that the fiber is actually the main part, but it turns into the secondary part, since, in the end, it is merely a guide for light. But, for example, to make the sensor, you must know how to use signal reading equipment, optical sources, modify the fiber to make it sensitive to what we want to work with. For instance, this includes going to a chemistry lab and learning how to synthesize nanoparticles, which are the sensor’s active elements. And then how to deposit them on the fiber, how to functionalize it, manipulate the samples to do the assignment, right, so it’s a very broad thing, very multidisciplinary.

90 – Yes, I think that working with problems from daily life... trying to bring this knowledge that seems to be a bit crazy, right, optical fiber is used to transport their home internet connection, how can it be used to ‘sense’ things... during my doctorate, my work was

about a sensor device to diagnose dengue [2 seconds]. It looks like that has nothing to do with things, but it gets there.

In these statements, we can observe this professor's efforts to develop research with the students that is related to their realities, as shown by the example of the investigation of the quality of milk that they buy in the supermarket, as well as the diagnosis of Dengue, which can help to solve problems in society. By explaining how formal content approaches daily life applications, Professor 3 demonstrates Pedagogical Content Knowledge throughout his statements, always seeking to use clear language to explain the content to the interviewer, who is unfamiliar with the functionalities and applications of optical fibers. His discourse exhibits the attempt to leave the abstract world (in his words "crazy") of theory and formality for that of the students' experiences. Thus, due to his efforts and the use of different strategies to explain fiber optics and sensors throughout the questions, such as showing an optical fiber and its applicability in daily life, it is possible to observe the presence of PCK in his teaching practice.

#### 4 – Professor 4 and Particle Physics

Professor 4 develops research in the field of Quantum Theory of Fields and, during the interview, states that she does not know how much a Licentiate degree would help in her education, since she has no knowledge of the contents discussed in the program. Since she only obtained a bachelor's degree, she attempts to repeat the standards of practice she considered "good" during her undergraduate years, and it is possible to identify the influence of previous practices experienced during her school and academic life, which contributed to the development of her views of the world and of education (BAKHTIN, 1997).

When questioned about her characteristics in the classroom, the professor spoke about how she plans her lessons and presents them. She indicated the need for communication between her and her students when

she stated that she always tries to encourage them, provoking questions through interactive questions in the classroom. In an excerpt from statement 50, it is possible to observe this concern, with the explicit presence of PCK in her statement:

50 – I keep trying to be the professor I would have liked to have somehow... yes, so, someone who shows interesting things to students, who encourages them, right. I try very hard, but I have been growing increasingly distant from this new generation. It is hard to stimulate them... I don't know, I don't see motivation in them as we used to see in the past. I like to try to encourage people, so I somehow try to tailor things to their interests... if I have a class from Engineering, I try to find an application in consultancy in an Engineering company or in the construction of a bridge... Anyway, within the person's field. So, in Geology I try to talk about wave propagation in earthquakes, this kind of thing... somehow associate it with a topic that could be of interest... motivate the students to want to learn that content which is sometimes very basic. So I keep trying to make these connections... If I am with a more advanced class, for instance, I try to make connections with research up ahead, because I think that sometimes that's what motivates students.

It is possible to observe an attempt to put herself in the place of a student to build a teaching identity. The term “very hard” can indicate that she understands she really makes an effort to motivate students in the sense of stimulating them to learn. It is also possible to note some disappointment regarding her students, when she emphasizes that she has become more distant from the new generation which, according to her, is not motivated to learn. There are no signs in her discourse of a critical reflection on how the undergraduate program – classes, evaluations, structure – can affect the students, or even an attempt to understand what is going on. There seems to

be a statement that there is simply no motivation to learn, as if this motivation could be transmitted to the students (Pozo; Gómez Crespo, 2001).

It is also possible to identify a clear attempt to adjust the lessons considering the students' fields of study, which demonstrates concern with the content that is presented. Still in statement 50, we have:

50 – I always try to begin my lessons with something I consider relatively simple and evolve from that to cover the whole spectrum, right, from the students who just want the basics to those that want something more advanced... sometimes that means straying from the syllabus, but it will connect that very basic topic with something that is more interesting. I try to find this sort of thing to motivate the students. And I like to write class notes on the board... at least that is what I did until now. I'm thinking about whether I should change things due to this new generation, but I think it's important, you know, to have content in the form of continuous text... And so I used to do this very detailed thing and all... on the board I try to use very clear handwriting, but it is a constant exercise and I try to encourage questions, I am always stopping class to let the students speak... I think that like, when there is this interaction between professor and students, everything works better because you adapt what you're saying, the questions... and you can reach people better. So I try, I think sometimes I try too hard, I keep asking... and if nobody volunteers, I conduct a vote... I pick something and ask "What do you think?" "Do you think it's yes or no? Does this behavior depend on particle mass or not?" Then we go and have a vote... I try to make everyone give an answer without forcing the matter, but I try to stimulate... I have felt that it is becoming increasingly difficult to get students to react in general.

The professor makes it clear that it is important to stimulate the students with questions during class, but it is also possible to notice that the questions used as examples in the interview are very straightforward.



Professor 4 tries, with the questions, to create a connection between more basic contents and more complex concepts, in an attempt to embrace the students' individuality and their "demands". The attempt to cover the entire "spectrum" of understanding and motivation suggests the identification of a certain degree of heterogeneity in the classroom, exhibiting important knowledge regarding the students and their characteristics. Thus, there is a clear intention to prepare lessons that are adequate for all students with their different challenges, which is also a characteristic of general teaching knowledge. In statement 56, when answering a question about her classroom methods, she once again brings up the attempt to prepare her lessons with concrete examples from students' daily lives, which can indicate PCK:

56 – Sometimes, I don't have much information, so what I do a lot is... for instance, if I am teaching a class to Geology students, I try to make a connection with the topics that have something to do with that, that I think have something to do with that, right, in my ignorance, that has something to do with what a Geologist or Geophysicist would do. I think a lot about encouraging them, and then in Oceanography, Engineering and so on, because those are the units I usually teach.

It is possible to observe a mastery over the selection and preparation of curricular material, as well as an attempt to search for pedagogical content knowledge when bringing content seen in the classroom closer to the students' academic realities. It is worth remembering that in statement 50, the professor declared that she "even strayed a little bit from the syllabus" in an attempt to motivate the students and bring content applications into the classroom, which also suggests an attempt to didacticize the contents.

Upon analyzing the CoRe, it was possible to observe that the professor sought to present two ideas: the "Composition of the Universe" and "Quantum Theory of Fields". She presented these ideas in a manner that includes a more theoretical and philosophical discussion, presenting the complexity of

mathematical formalism, with it being possible to infer that the professor masters the content she lectures about and has the intention that her students understand said content. In her discourse, there is an attempt to explain the concepts taught in the classroom.

110 – I know it is a very complicated formalism, that in part the Mathematics behind it is still being developed... so there are the Mathematics of the functional integral, the Feymann integral... which is very powerful, but at the same time we don't quite know how to define it mathematically... and there are many subtleties, so Theory of Fields is difficult for people because it involves many paradigm breaks, it involves concepts of normalization, right, the idea that there are infinities in nature that are "hidden" by the process of interaction... for you to deal with this idea "What is the mass of a particle?"...

When presenting the complexity of the Theory of Fields formalism, the professor suggests that it is "difficult for people because it involves many paradigm breaks". Despite demonstrating, in her discourse, a philosophical dimension of knowledge when bringing up the idea of paradigms (KHUN, 1962), we cannot infer whether the professor understands the importance of this discussion and its teaching in the classroom, which would facilitate the construction of a philosophical view of the knowledge in question. It is also worth mentioning that, based on her presentation of ideas, she attempts to adapt the language for the students to understand the concepts.

## **Conclusion**

Throughout this article, the importance of Shulman's base of knowledge was highlighted, especially PCK, as a tool for developing teaching strategies that are more relevant for professors and students. To obtain subsidies to reflect about university teaching, a discourse analysis was conducted with

university professors with the goal of recognizing the knowledge in their practices based on a theoretical-methodological approach of the Bakhtinian referential.

The analyses about PCK in the professors' discourses corroborate the idea that the presence of teaching knowledge interferes in teaching practices, allowing, when present, for there to be an adequate dialogue with students' knowledge and permitting an approximation between course contents and their historical-philosophical dimensions. Thus, content pedagogization is a fundamental skill for efficacious teaching and for more critical and reflective learning in Higher Education as well.

The dialogue between the considerations presented in the theoretical basis and the analyses conducted in this study reveals that the professors face challenges in their education as well as in their classroom work, which can lead to limitations in their understanding of the complexity of teaching practices. Thus, it is possible to conclude that it is necessary to generate reflections and debates about teaching and about content pedagogization so that they become frequent and guided towards strengthening the practices of professors in higher education.

Another important result from this study is the finding that, despite the limitations that were presented, the subjects make an effort to make knowledge accessible to students. However, this effort is not always sufficient for understanding teaching and learning processes, revealing the need to go beyond reflections and debates on the topic to reach concrete actions that value the underlying pedagogical theories pertaining to activities in classrooms, laboratories and the education of university students. One of these actions is the restructuring of university program course loads with the inclusion of courses that involve the subject of university teaching and that reach students in both licentiate and bachelor's programs, all of whom are potential teachers at different levels of education. In this sense, public policies encouraging the actions of these professionals and discussions about the

importance of university professors in the students' academic and professional education are more valued.

It is also worth pointing out that the so-called PCK is merely one dimension of teacher education, which is linked to other aspects that also deserve analysis and investigation.

Finally, it is important to highlight the role played by the subjects who, despite facing challenges such as the precarization of labor, the lack of investments in infrastructure and the pressure for academic productivity, continue to offer a quality education.

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Received in November 2003.

Approved in April 2024.