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Professional Learning of Physics Teachers in Lesson Study: Exploring Inquiry Tasks

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ABSTRACT

Background: Research concerning teachers' professional learning in lesson study has been highlighted in Physics teaching; however, studies that examine this process from the elaboration of inquiry tasks are still scarce. This kind of task makes it possible to explore physical concepts and relationships due to their open nature, which contemplates the students' interest, involves a practical dimension, and promotes successful learning situations. **Objectives**: To understand Physics teachers' professional learning in planning inquiry tasks to study Ohm's Law. **Design**: The investigation, of a qualitative and interpretive nature, involved 18 meetings of 2.5 hours. **Setting and Participants**: The lesson study engaged four secondary public school Physics teachers from the state education network. **Data collection and analysis**: The empirical research material consists of data produced in the development of the inquiry tasks, the transcripts of the audio recordings of the lesson study sessions, the investigative lesson, the material produced by the students, and the transcripts of the interviews carried out at the end of the lesson study. **Results**: The analysis showed professional learning about the development of inquiry tasks, analysis, argument, and inference of scientific knowledge, passing through engaging, exploring, explaining, elaborating, and evaluating activities on physical concepts. **Conclusions**: The research contributes to the knowledge development about teachers' professional learning, especially about the research lesson.

Keywords: Professional education; Inquiry tasks; Lesson study; Ohm's Law; Physics teaching.

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Aprendizagens Profissionais de Professores de Física em Estudos de Aula: Explorando Tarefas de Investigação

RESUMO

Contexto: Investigações sobre as aprendizagens profissionais de professores em estudos de aula vêm se destacando na área de Ensino de Física, entretanto ainda são escassas as pesquisas que examinam esse processo a partir da elaboração de tarefas de investigação. Este tipo de tarefas possibilita explorar conceitos físicos e suas relações devido ao seu caráter aberto, por priorizarem os interesses dos alunos e envolverem uma dimensão prática, além de promoverem situações de aprendizagem bem-sucedidas. **Objetivos**: Compreender as aprendizagens profissionais de professores de Física no planejamento de tarefas de investigação para o estudo da Lei de Ohm. **Design**: A investigação, de natureza qualitativa e interpretativa, envolveu 18 encontros de aproximadamente 2,5 horas. **Ambiente e participantes**: Envolveu quatro professoras de Física no ensino médio em escolas públicas da rede estadual de ensino. **Coleta e análise de dados**: O material empírico do estudo constitui-se dos materiais produzidos no desenvolvimento da tarefa de investigação, das transcrições das gravações em áudio das sessões do estudo de aula, da aula de investigação, do material produzido pelos alunos, bem como das transcrições das entrevistas realizadas ao final do processo. **Resultados**: A análise evidenciou aprendizagens sobre o desenvolvimento de tarefas de investigação, análise, argumentação e inferência do conhecimento científico, perpassando o envolvimento, exploração, explicação, elaboração e avaliação na abordagem de atividades sobre conceitos físicos. **Conclusões**: A investigação contribui para o desenvolvimento do conhecimento sobre as aprendizagens profissionais de professores, especialmente sobre a aula de investigação.

Palavras-chave: Aprendizagens Profissionais; Tarefas de Investigação; Estudo de aula; Lei de Ohm; Ensino de Física.

INTRODUCTION

The particularities of Physics teaching and the challenges of school education raise changes related to teaching approaches, models, and paradigms that need to coexist and compete, temporarily or permanently, with established procedures. According to García-Carmona (2020), insofar as an approach begins to stand out in relation to another which, at some level of consensus obtained acceptance and prominence, it produces a new pedagogical movement in scientific practices. For example, one of the widely valued approaches in Science teaching is the *inquiry-based approach*.

Inquiry-based science education (IBSE) promotes greater student interest in Science (Swarat, 2008), expands argumentative skills, and develops critical thinking (Lederman, Lederman, & Antink, 2013) and student knowledge (NRC, 2012). It can also favour the development of knowledge, reasoning, communication, and attitudinal skills (Baptista & Freire, 2006), producing beneficial effects on issues involving participatory, critical, and informed citizenship (Hodson, 2011).

The IBSE characterises a student-centred approach, the objective of which involves proposing challenges that allow students to explore concepts, ideas, and phenomena before the teacher's formal explanations (Marshall, Smart, & Alston, 2017). Understanding this focus is essential for the teacher who seeks to create and adapt the development of inquiry tasks that allow students to learn Science (Conceição, Baptista, & Ponte, 2019).

IBSE presupposes practices that encourage student protagonism, leading them to participate in the learning process actively. Through this approach, we seek to promote scientific literacy in terms of learning Science (conceptual and theoretical knowledge), learning about Science (understanding nature, history, methods, and their relationships), and learning to do Science (experience in scientific investigations and solving problems) (Hodson, 1998; Millar & Osborne, 1998).

Inquiry-based tasks emerge as a possibility to approach concepts and phenomena in Physics, fostering classroom strategies that favour learning *of* Sciences and *about* Sciences (Lederman, 2006). Such tasks bring contributions to the teacher, as the process of planning them constitutes a starting point to achieving the objectives proposed by the IBSE (Matoso & Freire, 2013).

The inquiry tasks have characteristics such as open character, are directed to the students' interests, and involve a practical dimension (Faria, Freire, Galvão, Reis, & Baptista, 2012). Moreover, they promote successful learning situations (Richit, Tomkelski, & Richit, 2021) by placing the student at the centre of this process (Bybee, 2006).

So, we consider it necessary to understand how teachers and students deal with this approach, by which it is possible to break with the expository ways of learning, overcoming the traditional roles of teacher and student in educational processes (Baptista, Freire, & Freire, 2013). Understanding the dynamics and potential of IBSE has contributed to the consolidation of training devices and approaches and new teaching strategies.

An approach increasingly used in the training of teachers of Physics, Mathematics, and other areas is the *lesson study*, a practice-centred approach to teacher professional development, supported by collaboration and reflection (Richit, Ponte, & Tomkelski, 2020). As they focus on teaching practice, classroom studies have based investigations on aspects related to learning curricular topics in Physics, including speed of sound (Conceição, Baptista, & Ponte, 2016).

We carried out an investigation seeking to understand the professional learning of teachers participating in a lesson study from the planning of investigation tasks. Supported by the perspective of *pedagogical content knowledge* – (PCK) by Lee Shulman (1986, 1987), we examined a lesson study with four Physics teachers, focusing on deepening Ohm's Law. Because they teach in the 3rd grade of high school, the teachers decided that the topic would be electricity. In refining the topics in this theme, they decided on Ohm's Law because they considered that students find it difficult to understand, mainly because its teaching is based on the enunciation of the law's equation.

INQUIRY TASKS

Recent studies have highlighted the importance of involving students in scientific investigation activities that require scientific reasoning skills (Teig, Scherer, & Kjaernsli, 2020), starting from the *inquiry, analysis, argument, and inference* (Kuhn, 2007). The inquiry and analysis phases from students' scientific reasoning skills in the search for the theory under study, by which they can identify the research question, formulate hypotheses, design experiments, and collect evidence. The argument and inference phases involve skills that imply the transition from evidence to theory through the analysis, interpretation, evaluation of evidence, reaching conclusions, and developing explanations (Kuhn, 2007; Kuhn & Pearsall, 2000).

Those skills play a fundamental role in implementing research practices and contribute to developing students' scientific understanding (Kuhn, Arvidsson, Lesperance, & Corprew, 2017; Kuhn & Pease, 2008). Teachers' planning of tasks can favour approaches to promote formative learning, contemplating the phases of investigation, analysis, argumentation, and inference.

Research tasks are presented to science teachers as a possibility to promote change in teaching practices. Due to its open nature, which allows considering different possible solutions or ways to obtain them (Rocard, 2007), research tasks favour students' learning by allowing them to develop and use their own strategies to solve them. The tasks promote challenging situations through which students can observe and explain phenomena, plan research, make predictions, draw conclusions, solve problems, and generalise (Conceição et al., 2019). Research dedicated to inquiry tasks has been valued as its benefits are recognised in the international literature (e.g., Furtak, Seidel, Iverson, & Briggs, 2012).

In developing investigation tasks, students, organised in small groups, work on a task by discussing and solving it and then discussing the resolutions with the whole class. In this dynamic, students play an active role in their learning, interpreting questions, representing information, and creating planning and problem solving strategies (Conceição et al., 2019).

Inquiry tasks promote changes in classroom routines by focusing on student actions and changing the teacher's role from a model based on the act of speaking to a facilitator of learning (Meadows, 2009). However, students may not immediately appropriate the changes introduced by the dynamics of inquiry tasks, either in what they do or in how they learn. This aspect highlights the importance of teachers' planning and development of research lessons to develop and understand knowledge, reasoning, communication, and attitudinal competencies (Baptista & Freire, 2006).

Bybee (1997) proposed a model for the development of inquiry tasks. In this model, based on the constructivist view of Science, Bybee suggests that inquiry tasks are developed in five steps: *engage, explore, explain, elaborate, and evaluate*. In engagement, students are motivated to study a specific subject starting from a problem situation, arousing interest and curiosity. In exploration, provided by group work, students make predictions, raise hypotheses, plan hypotheses testing, register observations, discuss with peers, compare results and possible explanations, and organise the information collected. In the explanation phase, students articulate observations, ideas, questions, and premises and are encouraged to use their own vocabulary to explain the concepts that emerge in the learning situation, use the results to support their explanations, and discuss critically with colleagues and teachers. In the elaboration, they establish connections, mobilising concepts and competencies that derive from the learning situation. In the evaluation, they reflect on the work developed (Bybee, 1997).

The Bybee model can be implemented in teaching planning through the following actions: (i) research on specific subjects *(engage)*; (ii) draw up one's own investigation plans *(explore)*; (iii) execute one's investigative plans *(explain)*; (iv) analyse one's data and communicate the results *(elaborate)*;

and (v) conclude about one's experiences regarding the subject learned and studied *(evaluate)* (Lourenço & Baptista, 2017).

For the teacher to develop a class based on inquiry tasks, Chapman (1997) suggests structuring it in three phases: *introducing the task, student's autonomous work, collective discussion and summing up*. Sierpinska (1998) states that the way communication flows during the class is fundamental. First, the teacher introduces the task, guides students on the class dynamics, and seeks to resolve doubts about issues that may hinder the task execution. In autonomous work, the teacher enables the collective discussion of ideas, fosters constructive and productive interactions, and collects information from individual student participation (Stein, Engle, Smith, & Hughes, 2008; Chapman, 1997). In the collective discussion and summing up, the teacher values student contributions, negotiates meanings, and encourages shared learning in the classroom (NGSS, 2013). To end the class, the teacher systematises the main points of the discussion, emphasising the language, the symbolic notation, and the concepts covered. This approach materialises a lesson where students develop knowledge by discussing ideas and negotiating meanings (Cakir, 2008).

Inquiry tasks allow students to enjoy new experiences. However, to develop this investigative attitude, the teacher needs to focus the class on the students' activities, ideas, and investigations, maintaining a questioning posture and minimising the level of support to the student (Ponte, Fonseca, & Brunheira, 1999).

Inquiry-based tasks eventually bring difficulties to students, mainly because they are not used to working with them, i.e., the approach defies their routine (Baptista et al., 2013). Also, as they are comfortable with teacher-centred teaching, students often find it had to adapt to a new classroom routine (Loughran, Berry, Mulhall, & Woolnough, 2006).

Another aspect we must consider is the level of difficulty and question formulation. About the level, it is the teachers' responsibility to ensure that the task is accessible to the students, avoiding a feeling of frustration and lack of motivation in its execution (Ponte et al., 1999). For this, question formulation is a vital point. It must be clear and explicit, as students may often have difficulties answering it otherwise (Ponte et al., 1999).

Finally, considering the benefits and potentialities of inquiry tasks for teaching and the difficulties that appear in the process, the teacher must plan them carefully. Based on planning, a favourable environment for carrying out tasks must be provided, and students should be encouraged to overcome obstacles that may arise since, after overcoming the difficulties, this approach constitutes a learning device (Baptista et al., 2013).

Teaching intervention is essential in the development of inquiry tasks. The teacher needs to examine what information is accessible to students and how they can use it, always considering the difficulties usually presented by them and aiming to assist them in learning (Le Hebel, Tiberghien, Montpied, & Fontanieu, 2019).

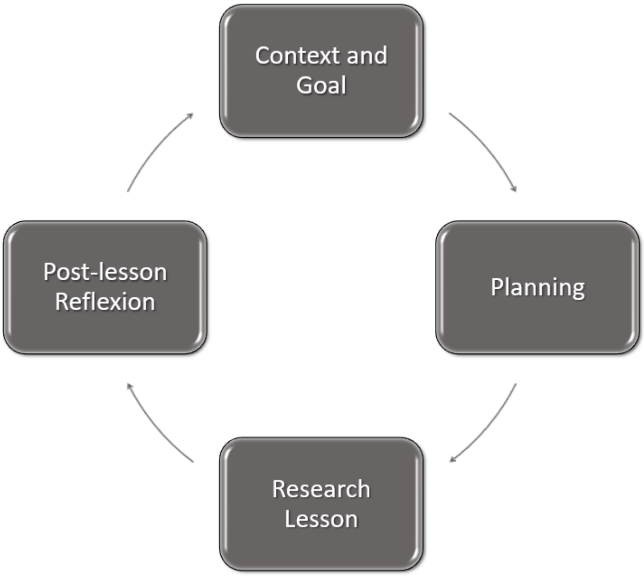
LESSON STUDY

Lesson study, *kenkyuu jugyou* in Japanese, is a teaching professional development approach widely practised in Japan. It is regarded as the main responsible for the improvement of teaching there (Yoshida, 1999; Richit, Tomkelski, & Richit, 2021). Lesson study is a work developed collaboratively by a group of teachers (Fernandez & Yoshida, 2004; Lewis, 2000, 2009; Lewis & Tsuchida, 1998; Stigler & Hiebert, 1999; Yoshida, 1999) that favours professional learning, especially on curricular topics and how to teach them (Baptista, Ponte, Velez, & Costa, 2014; Lewis, 2016; Murata, 2011; Richit & Tomkelski, 2020) and prepares teachers to improve their practices (Isoda, 2007). Due to the model characteristics, teachers develop knowledge about curriculum topics and their teaching and about student learning (Stigler & Hiebert, 1999).

In Japan, lesson study has a central structure constituted of four moments (Figure 1): identification of a *context* and definition of *goal* for the development of the research lesson, *planning;* in which a group of teachers work collaboratively over several sessions to plan a lesson on a specific curriculum topic; a *research lesson*, which is developed in a group of students; and *post-lesson reflection*, when the group meets to discuss and reflect on the students' actions in the investigative lesson, considering the aspects registered by the observers (Richit, 2020; Richit et al., 2020; Richit et al., 2021). The cycle can be repeated, deepening the study on a given content or starting again for new content (Fujii, 2016).

Figure 1

Lesson Study Cycle



The lesson study systematically incorporates teacher professional development in the classroom, anchored in the idea that a class contains many (if not all) of the critical components that teachers need to consider to improve their education (Sims & Walsh, 2009). It also promotes professional learning related to the elaboration of tasks on specific topics of the physics curriculum (Conceição et al., 2016), lesson planning, class observation and post-lesson reflection to discuss the teaching of the topic based on the students' actions (Fujii, 2016; Murata, 2011). Therefore, they favour changes in physics teaching (Conceição et al., 2016) by modifying classroom approaches.

Research on lesson studies as a teacher professional development process has shown promising results (e.g., Conceição et al., 2016; Juhler, 2018; Richit & Tomkelski, 2020; Sims & Walsh, 2009; Zhou, Xu, & Martinovic, 2016), but investigations with Science teachers are still scarce, mainly involving inquiry tasks in Physics teaching. Moreover, much research on lesson studies involves initial teacher education in Mathematics (e.g., Baptista et al., 2014; Ponte, Quaresma, Mata-Pereira, & Baptista, 2016) and few in Physics (e.g., Baptista et al., 2013; Conceição, Baptista, & Ponte, 2020; Conceição et al., 2019; Pektas, 2014; Rodrigues & Arroio, 2020).

In Conceição et al.'s (2019) research, which involved two cycles of lesson studies in an initial education course, the participants used research tasks to develop the theme of the speed of sound. In the first cycle, they learned to identify and understand the characteristics of the nature of the categories of inquiry tasks on the topic, discerning their development in the classroom and refining the class to improve students' performance when learning about the subject. In the second cycle, in a different group, the prospective teachers learned to observe the specificities of teaching the generating theme and improve the didactic material produced, i.e., the inquiry task and the lesson plan.

In Brazil, investigations on classroom studies in continuing education are mostly focused on actions with basic education Mathematics teachers (Richit & Ponte, 2020; Richit, Ponte, & Tomasi, 2021; Richit, Ponte, & Tomkelski, 2019; Richit & Tomkelski, 2020; Souza & Wrobel, 2017; Rincón & Fiorentini, 2017; Wanderley & Souza, 2020).

METHODOLOGY

The investigation[1], qualitative and interpretive, has to do with how problems involving the content are approached, leading the researcher to look for methods appropriate for the study of that content (Erickson, 1986). Qualitative research needs to include careful registering in writing and other types of documentary evidence (field notes, memos, student work, audio, video, etc.) of what happens during the observation; the subsequent analytical reflection on the documentary record; and reports through a detailed description (Erickson, 1986). Therefore, the qualitative and interpretive analysis allows understanding of the teachers' learning when they develop the inquiry tasks in this significant context.

Data were collected as part of the activities of a lesson study, which involved teachers who teach physics in public high schools of the state education network in Erechim, Rio Grande do Sul (RS), Brazil. The

[1] Approved by the Ethics Committee of the Institute of Education of the University of Lisbon, Lisbon – Portugal. Opinion Number: 4328 of 10/22/2018.

participants were four teachers (*Sol, Jô, Mel, and Roberta*[2]) who teach in the 3rd grade of public high schools in the region covered by the 15th Regional Education Coordination (CRE), based in Erechim, RS, and volunteered for the lesson study. The selection of participants was made possible by invitation or convenience, i.e., proximity to the investigator.

Aged between 38 and 52, the participants have between eight and 25 years of professional experience working in basic education[3] (final years of elementary school and high school) and youth and adult education[4] (EJA, in Portuguese) in high school.

The Organisation of the Lesson Study

The lesson study was composed of eighteen sessions of two and a half hours each, divided into five stages: (1) the theoretical constitution of the approach to lesson studies and analysis of the legal documents of the current Brazilian educational legislation; (2) analysis of research tasks for the classroom; (3) planning of the work plan for the first lesson addressing the investigation, reflections about, and refinement of the activity; (4) conduction of the first investigative lesson in the classroom, post-lesson reflections, and review of the work planning, and (5) conduction of the second investigative lesson, post-lesson reflection, and end of the work plan.

Fifteen sessions were held at the 15th Regional Coordination of Education (CRE), based in Erechim, RS; two sessions took place at Escola Estadual de Ensino Médio São José, Ponte Preta, RS – applying the diagnosis of inquiry tasks and second inquiry lesson; and one session was held at Escola Estadual de Ensino Médio Professor João Germano Imlau, Erechim, RS, Brazil – first inquiry lesson. In the two inquiry lessons, the teachers, first Jo

[2]All the names mentioned in this work are fictitious so as to follow the conditions of confidentiality and respect for the participants (DRE, 2016)

[3]In Brazil, basic education is formed by the following levels: early childhood education, elementary school, and high school. Elementary school is mandatory and lasts nine (9) years, and high school lasts three (3) years. Elementary school is organised in "elementary school - early years" (1st to 4th grade) and "elementary school - final years" (5th to 9th grade) (BRASIL, 1996).

[4] The EJA teaching modality is aimed at those who were unable to obtain their certificate in basic education at the appropriate age and is offered in the face-to-face or distance modality - EaD (BRASIL, 1996).

and second Sol, focused on the same Physics topic. Each class lasted 100 minutes.

The Structure of the Lesson Study Sessions

Stages (1), (2), (4), and (5) consisted of three meeting sessions each, and stage (3) consisted of six sessions, totalling eighteen sessions. “Electricity” was the Physics content chosen, directing the development of the lesson study on Ohm’s Law. The topic was settled based on the school calendar and prediction of contents to be taught during the research lesson.

Data Collection and Analysis

The empirical material consists of the data collected during the lesson study, including *the researcher’s field notes (FN) and teacher’s logbook (TL)*; *audio-recorded recordings (AR)* and transcripts; *documentary collection (DC),* the teachers’ written productions and also the students’ registers produced in the research lesson; and *interviews (I)* with the teachers. The researcher observed the sessions, assuming the role of an observer as participant to obtain detailed information about the process (Cohen, Manion, & Morrison, 2011).

Field notes are the registers of ideas, strategies, reflections, opinions, and patterns that emerge from the study, always based on detailed, accurate, and extensive notes (Bogdan & Biklen, 1994), which were systematised in the reports produced after each session. The interviews conducted after the lesson study were transcribed and put into writing and then incorporated into the empirical material of the investigation. We also incorporated into the empirical material the documents produced by the teachers during the lesson study, such as activity resolutions, representations, materials from classroom intervention, and the logbook, in which the participants registered their impressions and reflections at each meeting.

The analysis revealed different aspects intrinsic to the phases proposed by Kuhn (2007), revealing the internal dynamics of the phases and how they characterise the Physics teaching and learning processes, specifically on Ohm’s Law. Those aspects were examined, confronted, and organised according to their nature, constituting the categories of analysis: *investigation and analysis of inquiry tasks (IT),* which characterises scientific reasoning skills; *argument and inference in inquiry tasks*, relating to skills for directing evidence and conclusions. Each phase corresponds to a category to build the analysis matrix. Thus, according to content analysis (Bardin, 2003), each category is structured into subcategories, according to the model for the development of inquiry tasks by Bybee (1997), composed of a five-stage cycle: *engage, explore, explain, elaborate, and evaluate*. Engaging and exploring stages were related to the category of investigation and analysis of the TIs and the stages of explaining, elaborating, and evaluating characterise the category of argumentation and inference in TIs. This cycle is centred on planning inquiry tasks on Ohm's Law (Table 1).

Table 1

Categories and subcategories of analysis of teachers' learning in the development of inquiry tasks

Category	Subcategory
Investigation and Analysis of Inquiry tasks	*Engage* (problem situation/theory in evidence) *Explore* (predictions/hypotheses/tests/observations/organisation/discussion)
Argument and Inference in Inquiry tasks	*Explain* (articulating ideas/hypotheses/language/critical analysis) *Elaborate* (connections mobilising concepts/competencies) *Evaluate* (reflect on the whole/generalisation)

Through the empirical material analysis, the highlighted aspects were grouped into the categories and subcategories indicated in Table 1. The data are difficult to categorise, and the authors discussed them to reach a consensus. Non-consensus data were excluded.

RESULTS

The analysis, supported by the PCK perspective (Shulman, 1986, 1987), evidenced the teachers' learning in relation to the teaching of Ohm's Law, which constituted the two categories *of analysis, namely: investigation and analysis of the inquiry tasks*, encompassing scientific reasoning skills; *argument and inference in inquiry tasks*, considering the skills to direct evidence and conclusions.

Investigation and Analysis of Inquiry tasks

At the beginning of the planning, the teachers were involved in the study, reflection, and understanding of the physics inquiry tasks by analysing tasks developed by Portuguese secondary school teachers. This activity favoured learning about the structure and development of inquiry tasks, which guided the planning of the class on Ohm's Law, as Jô and Roberta point out.

> *[This activity] gave us new ideas, for me and for the group we were working with. It brought new ideas for the construction and elaboration of activities to be developed with the students, in research lessons [...] because it gives us guidance on how to start an research lesson. We have to build objectives for an adequate class, a class with an investigation in which the student discovers the steps to reach the formation of the concept. It was of fundamental importance so that we could look at it and say: "Well, let's do it this way, now with such content".* (Jô, E)

> *In those examples, we realised how we should prepare the tasks, polishing them. By making a construction of a simple example, then putting a more constructive example, then introducing a concept, and thus, creating a task that the student can solve from a concept they had before of the content. In this wa,y [the student] solves the task without even having had contact with that content.* (Roberta, E)

This experience constituted a starting point for the teachers' professional learning, insofar as they *got engaged* in understanding inquiry tasks for physics teaching. The analysis of the assignments developed by others provided them with elements for elaborating the task on Ohm's Law.

The planning enabled the deepening of the topic of Ohm's Law by the analysis of approaches to teaching materials, the study of their properties, the quantities involved in the equation of the Law, the measurement units usually used, the graphic representation, etc. Furthermore, it included a discussion about the strategies the teachers adopted in the classroom and to support students' learning in extracurricular activities. From those activities, the emphasis was directed to the question of investigation and analysis of inquiry tasks, involving the teachers with the topic, the tasks, the teaching of this topic, and the lesson study.

The study and discussion of the inquiry tasks, Ohm's Law, shared classroom experiences, and students' difficulties contributed to creating a task that aimed to lead them to a conceptual understanding of this topic. The elaboration of the task helped them develop the ability *to* anticipate, *predict* students' doubts and conclusions, *propose and test hypotheses* about the possible strategies of the students, and organise the class and the collective discussion.

In addition, they developed the ability to look critically at the predominant approaches in teaching materials adopted in physics, which are often restrictive. Mel highlighted her concern with the presentation of Ohm's Law in many textbooks, which promote a mechanicist knowledge construction.

> *If we think from the point of view of the construction of the concept [Ohm's Law], the way [the textbook] presented it does not lead to the construction of the concept. [The book] presented the concept, proposed some simple things, placed the representations in a disconnected way, and did not explore the relationships between them.* (Mel, RA)

According to Mel, many books do not promote students' construction of knowledge. Such materials present the topics directly, explaining the concept involved, stating properties, and proposing examples and exercises. In approaching the analysed materials, situations of exploration of Ohm's Law were not identified; instead, mechanistic activities and memorisation of the equation predominated.

The analysis of textbooks triggered reflections on the necessary attention to the structure and difficulty level of the task, as those aspects compromise the students' involvement. Jô highlighted that the task level of difficulty influences the students' participation, incurring the risk of abandoning the task due to problems in understanding or solving it.

> *When [students] start to understand things, they feel involved. But when they don't understand, they let it go, they don't want it anymore.* (Jô, RA)

Mel concludes that the investigation class needs to promote a different approximation from the one traditionally presented in teaching materials.

> *[...] I think that from this we are able to propose a very interesting [investigative] task, and I keep thinking: how will we do this in class with the students?* (Mel, RA)

The teachers learned the importance of elaborating tasks based on a problem situation close to the students' reality, favouring the construction of knowledge. The concern with the development of the inquiry task, associated with the subcategory 'engage' in a problem situation, made it possible to deepen the theory, Ohm's Law, and the tasks.

> *[The teachers] decided to start with something concrete. They suggested starting from a real context and developing the activity. [They suggested] to start by analysing, through tables and graphs, to get to the end, in the generalisation of the Ohm's Law equation, but without starting from the statement [definition of the Law], nor talking about Ohm [referring to the physicist Georg Simon Ohm], this will appear during the activity, towards the end of the class* (Researcher, NC)

Roberta highlighted the need to start from an investigation context involving something from everyday life.

> *[...] we had thought in that context [lighting item]. Somebody said: "[...] We could think as a context, the construction of a lamp", starting the task from there.* (Roberta, RA)

Mel added, by summarising the need for teachers to be involved in the development of tasks:

> *The inquiry task has this: it must be organised in a way that the student can have a sequence [...], and this here can be our main point. We have an idea that you will have to take something from everyday life to develop the task, and from it work the measurements, work on this issue of graphics, and even demystify this issue with electricity [students' difficulties in understanding this topic], this fear of theirs. They have a fear: "Oh, it's electricity, so I don't care, because I'm not going to be an electrical engineer, I'm not going to be an electrical technician". But, on a day-to-day basis, they will come across a situation where the shower has a problem, a light bulb has burned out; and then they will call a specialist to do it, or will they solve it in their own home?* (Mel, RA)

Mel evidences the understanding of different aspects. First, the task structure, which was new to the group. Also, the relevance of the task context, which is a starting point for the class because it engages students in the inquiry, guides the steps of the class, and stimulates the discovery and generalisation of the concept of Ohm's Law.

The teachers' learning was mobilised, especially in the process of planning the investigation class, according to the dialogue:

> Sol: *I've watched videos, looked for examples on the internet, but they all start with circuits, the battery with the ammeter to measure, mostly part of an experiment*.
>
> Roberta: *Cool, something practical!*
>
> Mel: *The idea would be to build that simple circuit. This idea is good!*
>
> Jô: *Interesting!*
>
> Sol: *I've watched several videos. Some [of them] go straight to the formula and others put this part of building, [...] for students to [connect electrical devices] see, measure [gauges] to achive the resistance [generalisation].*
>
> Researcher: *Great idea, now we need a context to carry out inquiry tasks on this problem situation.*
>
> Mel: *I thought of a lamp bulb or sidelamp [bedroom or table lamp], as we usually have this type of lamp in our work and study places.* (RA)

The analysis of situations involving Ohm's Law helped them define the construction of a table lamp as a context for the task involving components of electricity (wire, battery, and LED lamp[5]). The definition of this context was motivated by the interest in promoting an experimental activity in which students are encouraged to explore physical quantities through measuring instruments. In the Ohm's Law task, students were able to explore electrical quantities using a 'multimeter', took measurements of the electrical current intensity and potential difference of the generator (battery),

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[5]LED (*light emitting diode*) – is a semiconductor electronic component that has the property of transforming electrical energy into light.

and then analysed the relationship between these quantities to establish some pattern.

The discussion about the development of the investigation task gave them the opportunity to learn about conducting a class based on tasks of this nature.

> *We start from the context of the light fixture, circuit design, and data collection from the experiment. Then [the students] systematise the data in a table and draw the graph or graphs (I don't know how they will do it, let's leave it open), define a relationship [proportionality pattern] and an equation. The [second part of the] task could cite an example of an ohmic conductor, bringing part of the values [in a graph], then building a table, building a graph. And students will perceive the relationships and draw conclusions from the information contained. [For the third activity] we changed the logic. We started from another more concrete situation of a non-ohmic conductor. [From this, the student] simulates values, builds the table, and makes a graph with those values. [We ask] them to systematise in a table, and later to get the representation in the Law; what if we did an activity with two graphs a and b? [it was pending for discussion]. That is, explore those representations. And finally, they finish with the generic graph, making the relationship, extension, and abstraction with the formula [generalisation].* (Mel, DB)

In her logbook, Roberta summarised how the group decided to structure the task.

> *The elaboration [of the task] began, based on the objectives already defined and a pre-defined script, namely: A first task composed of a text for introduction, followed by two practical activities on simple circuit and some questions. The second part of the plan with activities developed starting from a graph that relates the voltage and the electric current of a simple circuit in which the students must find the constant of proportionality among other questions.* (Roberta, DB)

In one of the planning sessions, Roberta suggested working with situations that corroborate or contradict Ohm's Law (the maintenance of the proportion between the quantities involved).

> *Why don't we think, then, about an ohmic and non-ohmic graph at the same time? In that at some point it is ohmic, to some extent it is ohmic, therefore, it is in agreement with the relationship; but after a certain moment, it is no longer ohmic.* (Roberta, RAV)

Class planning allowed them to explore ohmic and non-ohmic graphs to lead students to identify the relationship between the quantities represented and visualise the disparity in representations between ohmic and non-ohmic, as Jô and Sol highlight:

> *I learned to use graphics to demystify the difficulty related to Physics; make a relationship with everyday life; check whether in the ohmic relation it is possible or not to invert a graph; concepts involved; mathematical relationship; multirepresentations; and [relationship between] practice and theory.* (Jô, DB).

> *I learned that research tasks engage the student in greater interest, take the teacher out of the traditional class, and develop the teacher's and the student's knowledge*. (Sun, DB).

According to the teachers, understanding concepts in Physics presupposes the students' involvement in challenging situations that are open to exploration, such as inquiry tasks. The appropriate choice of a problem situation or investigation context is very important, as it can enhance students' involvement and exploration. Those aspects favour discovering ways to obtain the relationships and physical concepts discussed. Finally, this process favours teacher learning, improving practice.

Argument and Inference in Inquiry tasks

The lesson study allowed them to revisit and deepen Ohm's Law, focusing the process on argument and inference. Mel highlights the main points for the task to meet the objectives:

> *The task will be attractive. They are led to obtain the concept of Ohm's Law from the search for regularities [relationships/mathematical proportions] in what they represent [...] and then [they] systematise some questions within it, which they ask for [the perception of these regularities]. So, I thought like this: first, we are going to do*

some experiments [practical activity] and the students will talk to each other and register the values of the measurements. [For this, we put] as much information as possible in the statement. I remember you talking about the care we need to take when preparing questions, how to say things! And then, with those values, they will start: "I take this one [and] divide it by this one; this one by this one; this one by this one; ah, but if I take this one by this one?". So, they will look for patterns, and eventually, either all, one, or some of them will achieve this constant [Ohm's Law]. (Mel, RA)

The task formulation, the language of the questions, the definition of hypotheses and anticipation of the students' difficulties and strategies favoured the teaching of Ohm's Law. The language of the statements was emphasised because, according to the teachers, it involves a specific language in the field of electricity and, with them, some properties. For the teachers, the language and the appropriate notation in the utterance favour the construction and concepts, the fixation of vocabulary, signs and symbols, and facilitate the students' understanding in solving the task. Another aspect valued by the group is related to the resources and materials for the class.

Jô: *That's it, just a small introduction of what will be done, right?! "Let's explore the necessary elements".*

Sol: *I was based on what was written before, and I confess that at the time I didn't know what to do with this other thread here, some students won't know either!*

Jô: *But, as there are boys there who already know how to do it, they will show it easily. Some of them have no idea, others already do.*

Roberta: *The interesting thing would be for us to deliver the whole wire, a longer piece of wire, and see what they do, how they do it...*

Sol: *So, do we leave "the wire"?*

Mel: *This question has now arisen because of the drawing. All right! I think we should leave "the wire" and let's see if [the students] cut it or ask for more wire, as they will actually do.*

> Roberta: *Wow! It's really good, girls! You gave me a lesson on how to write [the wording of] a question.*
>
> Mel: *And here we go straight to this question: "Sketch through a drawing", or are we going to try to connect something here?*
>
> Jô: *"Let's plan and build. Item a: sketch. Item b...".*
>
> (RA)

The language of the statements received the group's attention for enhancing (or marking) the understanding, the formulation of hypotheses, and the development of the students' reasoning processes. As for the materials used in the research lesson, the teachers consider that the task, supported by adequate materials, can promote learning.

> *[First, we heard each teacher about the possible difficulties that the student would have in the study of electricity]. From the difficulty that each teacher pointed out, we came to a common understanding [...]. With this anticipation of the student's difficulty, we were able to correct [the task] even before it happened, and not baffle the student.* (Roberta, E)

Teachers are also concerned about obtaining mathematical ratios and proportions, as mathematical analysis is essential in studying Ohm's Law and leads to understanding the concept. According to Georg Simon Ohm's (1789-1854) definition, for a conductor kept at a constant temperature, the ratio between the voltage between two points (U) and the electric current (i) is constant. This constant is called electrical resistance. The discussion below highlights this aspect.

> Jô: *[Analysing the relationship between the quantities involved in Ohm's Law, she says]: Yes, if you divide, this minus this, divided by this minus this, the result will be the same, because it is directly proportional.*
>
> Mel: *I found it interesting that those things were repeated. This has to do with the concepts that are involved, right?! And if students can perceive those things, and come to the conclusion that they are directly proportional physical quantities, that will be wonderful. Sometimes, the teacher talks all year about what are directly proportional physical quantities and they don't understand.*

Jô: *Yeah, the other day I was explaining why one quantity is directly proportional, why the other is inversely proportional, and I could not get them to understand. Then I started making the arrows. I wrote a compound rule of three there and worked it out with them. I said, "Do you remember the compound rule of three?" [Next, I solved the compound rule of three. Then, it became easy for them to understand, but even so, talking is more difficult; they don't know, it's not palpable!*

Roberta: *Ahem, and then, when you managed to make this relationship.*

Jô: *With the arrows, both downwards, the directly proportional one; one down and one up, the opposite. When the voltage increases, the current? The voltage increases, there is greater current flow; when you do the reverse process, it decreases, the one that was increasing in the process, on the return it will have to decrease; it is directly proportional. So, it was increasing, but when the process is reversed, it will have to decrease proportionally, as it increased proportionally.* (RA)

The teachers shared understandings about the relationship of proportion of the physical quantities explored in the task, seeking to lead students to identify the pattern of regularity between the quantities' electrical current' and 'electrical potential difference'. Through this negotiation, the group of teachers learned about Ohm's Law and ways of representing it, like the experience shared by Jô about a class that could not understand the proportion between quantities. Jô and Roberta emphasise the potential of investigation tasks to favour Physics learning.

The tasks [show] that a Physics class needs to be practical and dynamic. There is no way to teach Physics without [experimenting]. They also show that each student has different timing to understand and associate the solution method. There are several ways to understand, and each student brings a way to solve activities of this type. Some use more logic, others prefer to describe the resolution! So, a class with this type of task shows that students need to investigate, analyse, and then, complete the task. And this requires more from students and from us teachers, it makes us *think and not wait for ready answers from the teacher. In this way, certainly, the student learned! He understands, he learns, he doesn't forget anymore.* (Jô, E)

This type of activity leads the student to understand the physical phenomenon, the theoretical part of Physics, which is often abstract. And they don't have much abstraction. Students don't know how to abstract that part. So, I think this way in which the lesson studies develop the activity can lead the student to this abstraction. (Roberta, E)

The attention paid to the students' learning allowed the teachers to identify different rhythms and ways of thinking among the students and dissociate teaching from the teacher's exposure. Another aspect refers to the task evaluation processes.

What we could see is that each group of students had a slightly different response from the group next to them, or the group in front, because the way each one contributed was as a group, with each other. So, I think that the learning that I had by looking at this information that the students were presenting, at the resolution they were proposing one after the other, was great. We can see that there is not just one way to solve it [the students] managed to obtain an answer in a way that I, the teacher, had not imagined. So, it brings a lot of learning because a lot of things there, solving the activities, in short, the students brought their ideas, things that I, as a teacher, hadn't thought of, a more logical part of the situation, more placed in the day to day, placed as if it were something from everyday life, but the learning that I can take from it, from the student's error, because it is by making mistakes that they see the information that is not correct, correcting it, learning and no longer forgetting it. It added a lot in that sense, because we look at it that way, again and again and say: "But is there any other way to answer this question?". And there is, [the students] bring us information that we evaluate and see that yes, it is correct, as they put it. (Jô, E)

This experience led teachers to review their perspectives on student learning assessment. The task elaboration and its accomplishment in the research lesson allowed them to identify different possibilities and ways of solving the assignment that are not valued in conventional assessments.

Roberta valued the tasks for their potential to promote changes in Physics teaching.

> *We should start with examples, simpler examples and, from there, shape the concepts [as in the inquiry tasks] and not go directly to the concepts [traditional class]. We do not give ready-made concepts to the student [in classes involving inquiry tasks]. They will build the concepts from the examples we offer. I learned a lot. And that's what I'm trying to do in planning the other classes*. (Robert, E)

Roberta emphasised the importance of allowing knowledge to be constructed by the student in the interaction with the tasks. Sol and Roberta corroborate this perspective, adding that in the investigation process, it is important to start with a contextualised task, which is as close as possible to the student's daily life and allows students to work in pairs.

> *The task must start from a [situation] in their life. We didn't take something that doesn't exist, that is far from them. We chose something present for them as it was internally formed to achieve what we wanted.* (Sol, E)

> *Contextualised questions [help] in the students' better understanding. They understand better when the issue is contextualised and when they work in pairs, trios, groups where they can interact* (Roberta, E)

In the post-lesson reflection, the teachers analysed some of the students' difficulties that compromised the generalisation of Ohm's Law.

> Mel: *[Students] had to analyse, say what it was, what it wasn't, write the relationships, understand that it was proportional or not and obtain the generalisation, which was the formula.*

> Roberta: *They had a hard time getting there.*

> Sol: *Yeah, because they're not used to it.*

> Jô: *They had difficulty at first, but they exchanged ideas, tried division, multiplication; they commented to each other that there was a difference from one magnitude to another, they divided, multiplied, they did get the value, they associated it. Finally, they realised [...] that by dividing the voltage by the*

> *current, they get the constant, then one of them said: "It is always fifty, it is always fifty; ah, so you can divide".*
>
> Roberta: *The [student] multiplied and changed, and it wasn't. Then, when she started to do the division and she saw that it always gave the same value, "ah, so, that's it", then she understood it.*
>
> Mel: *That was fantastic! I remember that from that moment on, even without using the correct letters [R, U and i], she used a and b I think, she started doing a mathematical abstraction [a/b]. [Later] the boys saw the text and exchanged it, saying that it was u and i to define the law [Ohm's].* (RA)

Therefore, the lesson study allowed teachers to carry out professional learning about Ohm's Law and showed how inquiry tasks could favour changes in the teaching of Physics and their classroom practices. Based on the teachers' reflections, in Tables 2A and 2B, we systematised the typical aspects of the analysis categories addressed in this study.

Table 2A

Investigation and Analysis of Inquiry tasks

Subcategory	**Teachers' Speeches**
Engage ***(problem situation/ theory in evidence)***	- *We experiment with ideas for building and designing activities;* - *We had a guide on how to start an research lesson by examining assignments designed by others;* - *From the analysed tasks, we realised how we should prepare the tasks;* - *We build objectives for an adequate class, a class with investigation, in which the student discovers the steps to obtain the concept formation;* - *We chose to create a task that the student can solve from a concept that he has previously of the content.* - *We started building a simple example, then a more constructive example, then the concept;*
Explore ***(forecasts / hypotheses/ tests/ observations/ organisation/ discussion)***	- *We found that the way [the textbook] presents [Ohm's Law] does not lead to the construction of a concept;* - *We noticed that the book presents the concept, proposes some simple things, puts the representations in a disconnected way and did not explore the relationships between them;* - *[In planning the research lesson, we prioritise] starting from something concrete;* - *[They suggested a task for the student to start] analysing, through tables and graphs, obtaining the generalisation of the Ohm's Law equation;*

	- *[A task is structured] in a way that the student can have a sequence;* - *We define context as something from everyday life to develop the task, and from there, we work on measurements, work on this issue of graphics, and even demystify this issue with electricity;* - *[The task prioritised] exploring those representations;* - *[We assume that] students will perceive the relationships and draw conclusions from the information contained therein; and* - *[we believe that the students would get to the concept] by making the relationship, extension, and abstraction with the formula.*

Table 3B

Argumentation and Inference in Inquiry tasks

Subcategory	Teachers' Speech
Explain **(articulate ideas/ hypotheses/ language/ critical analysis)**	- *From the task, students will get to the concept of Ohm's Law from the search for regularities [relationships/mathematical proportions] in what they represent [...] and systematising them;* - *Through the task, they can do some experiments [practical activity] and the students talk with each other and register the values;* - *The inquiry task needs to bring as much information as possible into the problem statement;* - *Elaborating tasks requires care that we need to have when elaborating questions, how to say things;* - *From the task, students will look for patterns, and eventually either all, or one, or some of them will obtain this constant [Ohm's Law];* - *This anticipation of the student's difficulty [was crucial], we were able to correct [the task] even before it happened, and not baffle the student.*
Elaborate **(mobilising concepts / competencies)**	- *concepts that are involved;* - *The tasks [show] that a Physics class needs to be practical and dynamic.* - *Each student has a different timing to understand and associate the solution method and [this needs to be observed by the teacher];* - *So, a class with this type of task shows that students need to investigate, analyse, and then, complete the task;* - *The task leads the student to understand the physical phenomenon, the theoretical part of Physics, which is often abstract;* - *And this requires more from students and from us teachers, it makes us think and not wait for ready answers from the teacher;* - *This way in which the class studies develop the activity leads the student to this abstraction.*
Evaluate **(reflect on the whole/ generalisation)**	- *Each group had a slightly different answer from the next group, or the group ahead because the way each contributed was [different];* - *We can see that there is not just one way to solve it [the students] managed to obtain an answer in a way that I, the teacher, had not imagined;* - *[We learn a lot from] the student's error, it is by making mistakes that they see the information that it is not correct, correcting it, learning and*

	no longer forgetting it; - *[In classes involving inquiry tasks] we do not give ready-made concepts to the student, they will build the concepts from examples that we present to them;* - *[The context of the task was essential], because students understand better when the question is contextualised and when they work in pairs, trios, groups where they can interact;* - *From the proposed task, the students had to analyse, say what it was, what it wasn't, write the relationships, understand that it was proportional or not and arrive at the generalisation, which was the formula;* - *We noticed during the class that even without using the correct letters [R, U and i], one student used a and b. She started doing a mathematical abstraction [a/b]. [Later] the boys saw the text and exchanged it, saying that it was u and i to define the law [Ohm's].*

DISCUSSION

The analysis pointed to contributions from inquiry tasks to the study of Ohm's Law based on the phases proposed by Kuhn (2007), according to the model for the development of inquiry tasks (Bybee, 1997). When elaborating the task on Ohm's Law, the teachers delved into this topic and analysed different ways of exploring it in class, materialising professional learning about tasks, their possibilities, benefits, and challenges.

The teachers learned about strategies to promote the increase of scientific reasoning in the student (Teig et al., 2020) on how to conduct classroom investigations and analyse investigation tasks (Kuhn, 2007), promoting student engagement with challenging situations on Ohm's Law (Bybee, 1997). In addition, they developed learning about argumentation and inference (Kuhn, 2007) from a task that focuses on explaining, elaborating, and evaluating (Bybee, 1997).

Concerning *investigation and analysis of inquiry tasks*, the teachers carried out professional learning about the development of task-based teaching, which allowed them to consider different solutions or ways of solving them (Rocard, 2007), modifying their perspectives on the structure of the class and the role of the task context.

The lesson study favoured teachers' engagement in the analysis and elaboration of inquiry tasks, beginning a new pedagogical movement in their practices (García-Carmona, 2020). The analysis also showed the importance of considering task difficulty level so that the activities are accessible, clear, and explicit at the students' level, avoiding a feeling of frustration and demotivation in the execution of the task (Ponte et al., 1999).

Student involvement in the inquiry task is another aspect of professional learning, which points to the importance of task context. The task needs to encourage students' engagement in searching for ways to find one or more solutions (Lourenço & Baptista, 2017; Bybee, 1997) and provide a moment of involvement in a practical dimension (Faria et al., 2012), besides exploring knowledge, reasoning, communication, and attitudinal skills (Baptista & Freire, 2006; Bybee, 1997).

The analysis showed learning on the importance of tasks arising from situations in the real context of students, encouraging them to learn Science (Conceição et al., 2019; Swarat, 2008), and the possibility of promoting learning situations close to their reality (Richit et al., 2021), favouring the construction of students' knowledge (Lederman et al., 2013; NRC, 2012). The development of this knowledge has beneficial effects on issues related to students' participatory, critical, and informed citizenship (Hodson, 2011).

The *argument and inference in inquiry tasks* characterise the teachers' learning related to the actions of explaining, elaborating, and evaluating (Bybee, 1997). The act of explaining mobilised learning about the formulation of ideas, hypotheses regarding the students' reasoning processes, students' probable analyses and conclusions and rigour in the language and notation used in the task (Conceição et al., 2019). When preparing the task, the teachers needed to define objectives, resources, and adequate strategies to enhance the exploration of Ohm's Law, enabling students to deeply learn of Science and about Science (Lederman, 2006). The development of a class based on inquiry tasks on Ohm's Law allowed students to achieve objectives proposed by the IBSE (Matoso & Freire, 2013). And that aspect favoured the participants' professional learning on how to articulate classroom teaching objectives with general educational objectives.

Finally, the teachers' learning related to the evaluation stage refers to understanding the possibilities of modifying teaching and promoting situations in which students engage in tasks that contribute to scientific understanding (Kuhn et al., 2017; Kuhn & Pease, 2008). And by focusing class planning on activities that mobilise the students' questioning stance, the teacher minimises the level of support to the students (Ponte et al., 1999).

The analysis points out that inquiry tasks, due to their open nature, favour student learning by directing them to the development of activities that are according to their interests and that, when possible, engage them in more practical situations (Faria et al., 2012), such as the construction of the table lamp proposed in the task on Ohm's Law. Such situations provide students with new learning experiences (Richit et al., 2021).

Finally, the study highlights professional learning on how to promote the Physics teaching through situations that allow students to research, create strategies, develop research plans, promote challenging situations and execute them, plan, and make predictions, observe practical activities, obtain conclusions and communicate them, and generalise learning situations (Conceição et al., 2019; Lourenço & Baptista, 2017), as well as favour the professional development of teachers in their different dimensions (Richit, 2021).

CONCLUSION

The teachers developed learning about the phases of scientific investigation, passing through exploration, analysis, argumentation, and inference in the development of inquiry tasks, producing changes in the teaching of curricular topics, such as the Ohm's Law topic. The dynamics of the lesson study provided opportunities for learning about Ohm's Law teaching and, consequently, the need to plan activities that go through the stages of engaging, exploring, explaining, elaborating, and evaluating, converging on a deep understanding of the concepts. It also allowed them to make changes in the class and appropriate strategies and possibilities in approaching physical concepts.

The investigation contributes to developing knowledge about teachers' professional learning, especially about strategies to stimulate the research lesson, such as inquiry tasks. It can also mobilise changes in Physics teaching, covering issues involving teacher education and classroom practice. Among the possible contributions, we highlight: (i) implementation of new approaches and classroom strategies to favour student learning; (ii) value and enhance collaborative work among teachers, promoting joint planning in the development of tasks that involve conceptual and experimental situations; (iii) to favour student learning from tasks of this nature through students' involvement in challenging situations that are open to exploration that favour the discovery of paths that lead to the learning of different relationships, representations, and physical concepts; (iv) re-signification of students' difficulties and errors in learning Physics, insofar as they are taken as a starting point for teaching planning; and (v) appreciation of teacher training approaches that favour the professional development of teachers in their different dimensions.

AUTHORSHIP CONTRIBUTION STATEMENT

MLT designed the research and developed the theory. All authors adapted the methodology, performed the activities and constituted the data. All authors analysed the data, discussed the results, and contributed to the final version of the manuscript.

DATA AVAILABILITY STATEMENT

The research data will be made available by the authors upon reasonable request.

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