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ACTIONS THAT CONTRIBUTE TO SCIENCE TEACHING INVOLVING ARGUMENTATION AND THEIR RELATIONSHIPS WITH PEDAGOGICAL CONTENT KNOWLEDGE

Ações que contribuem para o ensino envolvendo argumentação e suas relações com PCK

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Abstract

In argumentation-based science teaching, teachers play an important role and are the main party responsible for the introduction of argumentation in classrooms. In this study, we discuss how actions that contribute to science teaching involving argumentation are expressed by a teacher on leading different types of didactic sequences, and how such actions relate to teachers' knowledge with regard to argumentation and teachers' pedagogical content knowledge (PCK). For this reason, we have constructed an instrumental case study, based on the observation of four didactic sequences led by an experienced teacher, and through interviews with her. From their analysis, we conclude that the goals set by the teacher in the didactic sequences have had an influence upon the actions that contribute to science teaching involving argumentation shown by the teacher, suggesting a strong link between the elements of PCK and those of the Knowledge for Teachers' Actions through Argumentation. As possible consequences, we draw attention to the need to add value to a hybrid method for teaching argumentation, involving implicit and explicit teaching, as well as the proposal of the set of actions that contribute to science teaching involving argumentation. This can contribute towards the investigations into the role of teachers within argumentation-based science teaching, and to teacher education.

Keywords: argumentation; teacher actions; teachers' knowledge of argumentation; pedagogical content knowledge; regular teaching context.

Resumo

No ensino de ciências envolvendo argumentação, professores desempenham um papel importante e são os principais responsáveis pela introdução de argumentação nas salas de aula. Neste estudo, discutimos como as ações que contribuem para o ensino de ciências envolvendo argumentação são manifestadas por uma professora ao conduzir diferentes sequências didáticas, e como tais ações se relacionam ao conhecimento docente relativo à argumentação e ao conhecimento pedagógico de conteúdo (CPC). Para tal, construímos um estudo de caso instrumental, a partir da observação de quatro sequências didáticas conduzidas por uma professora experiente e por meio de entrevistas com ela. A partir de sua análise, concluímos que os objetivos propostos pela professora para as sequências didáticas influenciaram as ações que contribuem para o ensino de ciências envolvendo argumentação manifestadas por ela, sugerindo uma forte ligação entre os elementos do CPC e os dos Conhecimentos para Ação Docente em Argumentação. Como implicações desse estudo, chamamos a atenção para a necessidade de valorizar um ensino híbrido de argumentação, envolvendo ensino implícito e explícito, bem como a proposição de um conjunto de ações que contribuem para o ensino de ciências envolvendo argumentação. Isso pode contribuir tanto para investigações sobre o papel de professores frente ao ensino de ciências envolvendo argumentação quanto para a formação de professores.

Palavras-chave: argumentação; ações docentes; conhecimento docente de argumentação; conhecimento pedagógico de conteúdo; contexto regular de ensino.

INTRODUCTION

Science teaching involving argumentation has been the subject of heated discussions over the last few decades (Chen, Benus, & Hernandez, 2019; Driver, Newton, & Osborne, 2000; Jiménez-Aleixandre & Erduran, 2008; McNeill & Pimentel, 2010), with repercussions in the curricular programs suggested on official documents, presenting guidelines for primary education in different countries (e.g. DFE, 2014; NRC, 2012). Researchers have given special attention to teachers' knowledge (Chen et al., 2019; Christodoulou & Osborne, 2014; Evagorou & Dillon, 2011; McNeill & Pimentel, 2010; Simon, Erduran, & Osborne, 2006; Yilmaz, Cakiroglu, Ertepinar, & Erduran, 2017). Particularly, some authors have taken the teachers' knowledge related to argumentation as a specific kind of Pedagogical Content Knowledge (PCK) (McNeill, González-Howard, Katsh-Singer, & Loper, 2015; McNeill & Knight, 2013; Sengul, Enderle, & Schwartz, 2020; Wang & Buck, 2016; Yilmaz et al., 2017), *PCK for argumentation*. In this regard, such authors have based themselves on the PCK model as proposed by Magnusson, Krajcik and Borko (1999) and adopted the idea of *PCK for argumentation* to investigate the teachers' knowledge related to argumentation or some of its dimensions, such as instructional strategies specific to argumentation.

Moving in another direction, we have discussed the risks of the use of the construct PCK for argumentation to characterize or investigate the knowledge related to argumentation (Ibraim & Justi, 2021b), mainly considering the complexity of teachers' knowledge, highlighted in recent models seeking to characterize them (e.g. Carlson & Daehler, 2019; Gess-Newsome, 2015). This means that we defend the view that the use of this construct is limited to educational situations where the object of knowledge is argumentation itself; in other words, those where there is the explicit teaching of argumentation. However, in situations where the teacher's main aim is to teach content knowledge, it is difficult to map or interpret the dimensions of PCK for argumentation. This is because, in these cases, argumentation can be taken as an orientation toward teaching science, or an instructional strategy that contributes to conceptual learning, thereby characterizing the implicit teaching of argumentation. Therefore, in our view, the construct PCK for argumentation does not contribute for discussions about the links between knowledge related to argumentation and the other elements of teachers' knowledge used during science lessons, which are the focus our discussion in this paper.

Some discussions on PCK can shed light on other models that can better characterize the teachers' knowledge related to argumentation. In Ibraim and Justi (2016), based on the understanding that teachers need to have both content knowledge and pedagogical knowledge so they can teach somebody something, we have proposed the model Knowledge for Teachers' Actions through Argumentation (KTAtA). In the current study, based on the element T*eachers' Actions that Contribute to Science Teaching Involving Argumentation* mentioned in the KTAtA, we seek to investigate: How are actions that contribute to science teaching involving argumentation shown by a teacher when leading different types of didactic sequences? How can the actions manifested by the teacher be related to the PCK's elements mobilized by her when leading different types of didactic sequences?

Thus, based on an instrumental case study (Creswell, 2013; Grandy, 2010), we have investigated the actions carried out by a teacher on leading three didactic sequences involving implicit argumentation, and one didactic sequence involving explicit argumentation. Being based on a teacher's own practice, this study can light up the understanding of the possibilities for occurrence of an argumentation-based style of teaching in regular classrooms and shed light on the interactions between the different types of teachers' knowledge. We therefore also seek to contribute for discussions about teachers' knowledge related to argumentation and its relationships to PCK, as well as to provide grounds for thoughts on teachers' education.

THEORETICAL BACKGROUND

Science education involving argumentation

Argumentation is a scientific practice related to production of knowledge, to the justification of suitability of models, explanations and theories as created based on available evidence analyzed based on prior knowledge (Osborne & Dillon, 2010). Argumentation is also present at the moments of validation and legitimation of knowledge, when scientists analyze the consistency of scientific statements, considering available evidence and theoretical models (Osborne, 2016), and in the processes of communication of knowledge, given that they seek to convince peers about the validity thereof, which means the possibility of existence of criticism and rejection on the part of the scientific community (Williams, 2011). In this regard, Jiménez-Aleixandre and Erduran (2008), sum up the main aims of argumentation as being: (i) justification or evaluation of knowledge claims, meaning producing arguments in which claims and evidence are connected through justifications; and (ii) persuasion of an audience, where individual people get involved in a dialogue process seeking the convincement of the other or the presentation of criticism to the ideas considered. In this way, we can think of argumentation in terms of two core dimensions: the individual dimension, which involves the use of justification for the construction of arguments, and the social dimension, related to a process of negotiation between people with different or opposing views (Jiménez-Aleixandre & Erduran, 2008).

In science education, the insertion of argumentation has been defended as a way of contributing to authentic teaching, so as to provide students with hands-on experience of scientific practices (Cavagnetto, 2010). From the involvement of students in the scientific practice of argumentation, it is expected that they may have opportunities to discuss the processes that lead to the acceptance of a given idea or theory, based on epistemic criteria, meaning that they shall be able to accept science as being a social process (Driver et al., 2000; Osborne, Erduran, & Simon, 2004); and understand what scientists do to establish confidence and credibility of the knowledge thus produced (Osborne, 2016; Osborne & Dillon, 2010). Therefore, science teaching involving argumentation may contribute so that students may also develop their own scientific knowledge (Driver et al., 2000; Duschl, 2008; Duschl & Grandy, 2013; Osborne, 2016).

Another contribution of science teaching involving argumentation is related to the possibility of the teacher having access to how students internalize their scientific concepts based on situations where they state their justification or construct their own arguments (Jiménez-Aleixandre & Erduran, 2008). This is because, in situations such as this, students need to get scientific models as a way to back up their own interpretations about the phenomenon being discussed and their own arguments.

These possible contributions largely depend on the teachers' content knowledge about argumentation, and also their pedagogical knowledge, both to get the students involved in the construction of claims using supporting evidence and to query them and challenge them to look into their very own claims and those of their colleagues (Berland & Hammer, 2012). Such importance of these types of teachers' knowledge suggests the need to discuss their constituent elements that make an effective contribution to the teachers' work as part of teaching involving argumentation.

Pedagogical Content Knowledge

Originally proposed by Shulman (1986), PCK concerns teachers' knowledge related to the teaching of a certain unit of knowledge to specific students, as well as to proper instructional strategies and knowledge of student conceptions related to the scientific content. In general, a broad PCK has been associated with good teaching practices.

Based on Shulman's ideas, Magnusson and collaborators (1999) present a specific PCK model for the area of natural sciences, in which PCK includes the *orientations to teaching science*, which are formed by the *knowledge of science curricula, knowledge of students' understanding of science*, *knowledge of instructional strategies* and *knowledge of assessment of scientific literacy*. This model has been widely used in the literature (Kind, 2015) because it contributes to the understanding of the elements that constitute the teachers' PCK.

Recently, Carlson and Daehler (2019) proposed that teachers could possess different domains of PCK, which have different origins yet mutually influence each other. According to the authors, teachers present an *enacted PCK*, with regard to knowledge invoked by the teacher within the classroom environment; and a *personal PCK*, comprising their teaching and learning experiences, the interaction between them and other individuals in the area, such as other teachers and all the students with whom they have liaised, as well as the teachers' own other professional experiences. These two distinct domains of knowledge are influenced by the *learning context* in which a given teacher is inserted, as any educational process takes place within a given context. Learning contexts can be understood as time and space as defined by educational policies or by being related to the scholastic field or the profile of this teacher's students. In addition, Carlson and Daehler (2019) suggest the existence of a *collective PCK*, which refers to the knowledge base of science teachers for teaching a certain topic to specific students within a set teaching context. The collective PCK is shared between the professional people in the area and has an influence upon the formation of personal PCK. All the PCK domains and the learning contexts are influenced by a teacher's knowledge base, consisting of his/her content knowledge, knowledge of student, pedagogical knowledge, curricular knowledge and assessment knowledge, which have been described by Shulman (1986) and Magnusson and collaborators (1999).

Based on that, the way in which teachers shall get this knowledge involved within their classrooms shall suffer strong influence from learning contexts in which they and their students are inserted, and through the teachers' personal PCK. Therefore, we consider that the teachers' knowledge related to argumentation is directly linked to different domains of their PCK.

Knowledge for Teachers' Actions through Argumentation

Knowledge for Teachers' Actions through Argumentation (KTAtA) was proposed by Ibraim and Justi (2016), aiming at listing and establishing relations between elements of knowledge related to argumentation that may guide teacher training programs with an emphasis on argumentation and contribute to discussions on the specificity of this knowledge. KTAtA consist of the following elements:

The *knowledge about argumentation* is suggested taking into consideration the possible ways of understanding argumentation (from the Logic, Dialectics and Rhetoric perspectives (Wenzel, 1990)), as well as our understanding of the contribution of each of these perspectives to science teaching, as we consider that basing science teaching on only one of these can be limited.

The logical perspective aims at the production of arguments. From this, we establish the *knowledge about the basic elements of an argument*, meaning the understanding that *claims* are answers to questions or conclusions (Toulmin, 1958); *evidence* is data that can give support to claims (Jiménez-Aleixandre, 2010); and *justification* is the connecting link between evidence and claims (Jiménez-Aleixandre, 2010).

On the other hand, the rhetoric and dialectic perspectives give emphasis, respectively, to the process and to the context of argument production, bearing in mind the objectives connected to it. By linking these perspectives with the classroom context and the production of scientific knowledge, we may conclude that teachers could understand that scientific statements are produced based on the coordination of evidence and justifications and that, therefore, they can be rejected when there is new evidence or when interpretations of a given evidence in the light of other theoretical models do not give support to that knowledge anymore. Additionally, different individuals can interpret the same evidence in different ways, as well as suggest alternative explanations for the same phenomenon. These considerations can be related to the field of argumentation from the argumentative skills (Kuhn, 1991), in a way that means teachers should know that: (i) *refutation* is an argument that invalidates the viewpoint of the other participant in the dialogue, be it through the decrease of the credibility of the evidence which supports the other person's argument or through valuing the personal argument; (ii) *alternative theories* are different interpretations for the same evidence; and (iii) *counter-argument* is an argument that reduces the validity of the opposite viewpoint, based on the presentation of an alternative argument or a criticism against the content as expressed in the opposing argument (Kuhn & Crowell, 2014).

In the KTAtA model, another element that comprises the *knowledge about argumentation* is the meaning of *argumentative situations*. These can be understood as those seeking: (i) justification or evaluation of knowledge statements in the light of available evidence; and (ii) persuasion of an audience with regard to the validity of a given argument (Jiménez-Aleixandre & Erduran, 2008). The understanding of argumentative situations can support the teacher when teaching about both the use of the elements of an argument and the argumentative skills or to get students involved in this drive to engagement. Additionally, this knowledge can contribute to the teacher's perception about such situations in the scientific field or during the process of construction of knowledge.

On the other hand, knowledge concerning the pedagogical aspects in the argumentation-based context was thought about based on programs for teacher education focused on the development of knowledge of argumentation, as described in the literature (specifically, McNeill & Knight, 2013; Simon et al., 2006; Zembal-Saul, 2009). In all these papers, the education programs emphasized the development of activities based on argumentation and teaching strategies coherent with the perspective of argumentation. We therefore assume that the fact that different programs give attention to these elements means that they are essential for the teachers' performances in teaching contexts involving argumentation.

Thus, we list the following as pedagogical aspects in the argumentation-based context in the model: (i) the knowledge of teaching strategies coherent with argumentative practice, that is, teachers' knowledge of the different strategies which they can follow in a move to get students involved in an argumentative environment or that can make it easier for the students to learn about specific aspects of argumentation; and (ii) the knowledge about instructional materials, which is coherent with the perspective of teaching through argumentation involving both knowledge about resources (like a specific case which may encourage argumentative situations) and with the understanding of the core characteristics of this type of material (such as the fact that they necessarily involve problems which permit the occurrence of multiple answers).

By taking into account some other relevant ideas like Grossman's (1990) criticisms on the need that elements related to practical teaching situations were assumed as constituents of PCK, and Gess-Newsome's (2015) inclusion of the elements *classroom practice* and *context* in recent versions of the PCK model, we consider that another element essential for KTAtA are the *actions that contribute to science teaching involving argumentation*. This element was proposed in the model considering the importance of the teacher knowing how to articulate and use knowledge regarding argumentative practice in the classroom.

In the specialized literature in this area, especially setting out from studies by Simon (2006), Mork (2005) and Yilma *et al.* (2017), we find instructional strategies for argumentation that could be used by teachers to start, sustain, and nurture argumentation in the classroom. Even though we recognize and accept the validity of the strategies that the authors have presented, we also consider that it is not appropriate to portray them as instructional strategies because, based by the perspective of teachers' knowledge, the fact is that the knowledge of instructional strategies refers to teachers' knowledge of strategies that could be used to help students understand specific concepts or that are coherent with the teaching of content of a given area (Magnusson et al., 1999). Thus, as we understand that argumentation could be either an object of teaching in its own right or a strategy or an orientation for the teaching of specific curricular content, we have opted for consider that instructional strategies are different from knowledge regarding actions that contribute to science teaching involving argumentation. In addition, on distinguishing between the teachers' knowledge as used in the classroom from that knowledge used during planning, we may investigate how teachers plan and conduct science teaching involving argumentation, what kind of science teaching involving argumentation teachers actually plan, or what teachers' explicit and implicit objectives are.

METHODOLOGICAL ASPECTS

In this study, we have chosen the case study (Creswell, 2013; Merriam, 2009) as the investigation strategy. In particular, we have built a case study that contains strong characteristics of an instrumental case study, in which the researcher tries to understand one specific issue, a problem etc. This means that the case selected has the function of providing insights into a certain issue (Creswell, 2013; Grandy, 2010). In this paper, we seek to promote discussions about how actions that contribute to science teaching involving argumentation are shown by a teacher on carrying out different didactic sequences in a classroom. From this point on, we seek to discuss possible links between the actions that contribute to science teaching involving argumentation and other types of the teachers' knowledge related to teaching.

Context of data collection

We recognize that contexts concerning teachers' qualification play a key role in the development of teaching-related knowledge regarding argumentation. So, we invited a teacher who has taken teacher qualification in Chemistry – the main area of her content knowledge – and has also completed master's and doctoral studies in Education and, mainly, who is involved in favoring students' comprehensive learning – which means that she follows an investigative orientation to teaching science. At the time of the data collection, she had twelve years' experience in high school teaching and some experience in working on investigative projects within science teaching, in other words, she had knowledge about science teaching strategies. The decision to work with this teacher was the result of her showing the desired profile. The teacher agreed to take part in the research and, seeking to preserve her identity, we shall use the fictitious name Emma whenever we need to refer to her.

At the starting of the study, Emma had not participated in any specific teacher training program focusing on argumentation, such as those described in the literature (Ibraim & Justi, 2016; McNeill & Knight, 2013; Simon et al., 2006; Zembal-Saul, 2009). However, seeking to reduce her apparent shortcomings in specific qualifications in argumentation, before the data collection gets under way, the first author (i) observed some of her lessons, seeking to characterize her practice in that teaching context, especially identifying aspects that could somehow be connected to science teaching involving argumentation; and (ii) interviewed her, trying to investigate the reasons behind her actions in the classroom, and also her general ideas regarding teaching through dialogue and argumentation. In addition, based on previous experience in investigation of the contributions of an explicit program for qualification in argumentation to the development of KTAtA (Ibraim & Justi, 2016), we have carried out general discussions with the teacher about the basic elements of an argument, the contributions of argumentative practice for the development of the students, and the use of social and scientific issues within science teaching.

Based on the KTAtA model, we viewed the importance of addressing issues concerning actions, strategies, and materials that could favor science teaching involving argumentation. However, instead of presenting a variety of actions, strategies and materials as described in the literature, we have decided to approach these elements of knowledge based on Emma's teaching practice, which was possible through the observations previously made in her classroom. On taking up this posture, our intentions were: (i) to provide the teacher with moments for thought; (ii) to establish relations between her orientations toward teaching science, her practice, and the science teaching involving argumentation; and (iii) to get her involved in consideration about how to bring about, and how to conduct, argumentative situations. All the discussions with the teacher were video recorded.

The data was collected in a classroom with 35 students aged between 16 and 17 years old, in a public school in the Southeast of Brazil. They all agreed to participate in the research, and had their identities kept secret with the use of fictitious names.

In the classroom, the data collection occurred in the second half of the scholastic year, this being the first when the students had lessons with that particular teacher. Emma reported that, at the start of the first term, the pupils showed signs of discontent with the fact that they were questioned during conceptual discussions because, as a rule, they were used to teacher-centered tuition, in which teachers presented the content without any questions being raised about their ideas concerning any related issue. However, in the second half of the year the students stated that they were more accepting of this practice used by the teacher, as everyone participated actively in group discussions, and many even participated in discussions with the class group.

For a period of four months, we have observed and video-recorded all the lessons given by Emma to this particular group. The lessons were 50 minutes long and took place twice a week. Considering the limited scope of our research questions, the set of data here analyzed consists of 13 of these classes, which included some intense moments of discussion between the teacher and the students (either individually or in groups). We did not consider the lessons where there was little, or no, interaction between the teacher and the students, like exercises solving classes and tests. Specifically within the period of data collection, there were: (i) six lessons of a didactic sequence on chemical kinetics, of which we analyzed three lessons as characterized in Table 1; (ii) eight lessons from a didactic sequence on the thermodynamic aspects of chemical processes, of which three were analyzed; (iii) three lessons addressing the didactic sequence on argumentation; and (iv) eight lessons from a didactic sequence on chemical equilibrium, of which four lessons have been analyzed. The lessons that we analyzed are briefly presented in Table 1.

Table 1 – Characterization of the lessons analyzed.

Didactic sequence	Lessons[1]	General Context	Main Remarks
Chemical kinetics	L1	Discussion of the problem question: Why does a candle go out when you blow it while coal ignites when you blow it? Discussions about: The burning of the wick of the candle; the concept of a catalyst; functions of combustible and comburent substances in combustion reactions.	During the discussion, a new question arose: What is the role of paraffin in the candle? Is it a structuring element, is it to keep the wick upright, or a form of fuel? This problem became the object of discussion within the class group, and the teacher suggested students to carry out an experiment at home (burning two candles of different thicknesses), the results of which would be discussed during the following lesson.
	L2	Discussion about the open experiment carried out by the students.	During the lesson, Emma asked the students to present what they had observed in the experiment, also describing how they carried out the experiment, comparing the procedures followed and possible links between these and the results found. She also encouraged them to interpret all the observations presented. At the end of the lesson, Emma asked the students to search the meaning and the function of catalysts.
Chemical kinetics	L3	Discussion about the construction of a graph involving the variables: energy and path of reaction. Introduction of the phrase activation energy and of its meaning. Discussion about the concept of a catalyst and its effects upon chemical reactions.	During the lesson, the students and the teacher discussed the scientific interpretation of what they had worked on in the previous classes; and about how to represent the energy of reagents and products in a combustion reaction.

[1] The numerical code of the lessons in Table 1 does not necessarily mean that the lessons were consecutive.

Table 1 - Characterization of the lessons analyzed (continuation).

Didactic sequence	Lessons	General Context	Main Remarks
Thermodynamic aspects	L4	The students performed, and then discussed, an experiment involving the reactions between ammonium thiocyanate (NH_4SN) e barium hydroxide ($Ba(OH)_2$ and between sodium hydroxide (NaOH) and aluminum (Al).	During the group discussion, Emma asked the students about their experimental observations, trying to get them involved in the interpretations of these observations based on chemical knowledge such as chemical kinetics, chemical reactions, and chemical interactions.
	L5	Continuation of the group discussion about the experimental activity that had been carried out in the previous lesson. Experiments were carried out as demonstrations, by the teacher.	On carrying out the experiment, Emma brought a new element (use of a moistened wooden plaque in contact with the Erlenmeyer flask containing NH_4SN and $Ba(OH)_2$), which could be used as a piece of evidence to show that the reaction that unfolded is endothermic, as the water on the plate freezes. During the discussion Emma raised the question: 'where' does the energy that the system absorbs in the experiment involving NH_4SN and $Ba(OH)_2$ go to?
	L6	Rediscussion of the issue raised in the previous lesson. Construction of a qualitative graph involving the variables: enthalpy and path of reaction for endothermic chemical reactions. Introduction of the concepts exothermic and endothermic reactions, and of their meanings.	The students and the teacher discussed the energy aspects involved in the reactions studied in lessons 4 and 5. At the end of the lesson, the students reached the conclusion that: (i) to determine if a reaction is endothermic or exothermic, one must consider the variation of energy involved; (ii) the reaction between NH_4SN and $Ba(OH)_2$ is an endothermic one.
Argumentation	L7	Beginning of the mock trial. Emma highlighted the question to be discussed: Should fast-food chains be held responsible for health problems in their consumers? Discussions on how to construct arguments to be used in the different stages of the mock trial and also about the importance of the use of reliable data as evidence.	The students gave the teacher their impressions and observations about the documentary film "Super Size Me", which they had watched previously at the request of the teacher. Emma then introduced the mock trial activity to the students, highlighting that the class would be divided into three groups: one in favor and one against fast-food companies being held responsible for the health problems of clients, and jury; and that the trial would be divided into three stages: the presentation of initial arguments, the reply, and finally the rejoinder. Emma also discussed the importance of using reliable data to construct valid arguments, the role of evidence and justification in the construction of valid arguments for rebuttal. At the end of the lesson, she asked each student to come up with arguments for both sides, as the groups would only be defined later.
	L8	General discussion on the arguments expressed by the students for both viewpoints involved in the jury. Group discussions about arguments, replies and rejoinders, and about the strategies to be used within the mock trial activity.	Emma started the lesson by making a general assessment of the arguments expressed by the students in the written activities they had handed in. She highlighted the lack explicitness of justification; the frailness of the arguments produced, as in many cases there was no articulation between evidence and the claim; the need for the students to use scientific knowledge, especially in thermochemistry, as grounds for their arguments; and how the arguments could be assessed in relation to the viewpoint to be defended.
	L9	Discussion on the arguments used by students during the mock trial session that took place in the previous lesson.	Emma encouraged the students to evaluate some of the arguments that they used during the mock trial, stressing the lack of connection between the evidence presented and the claim defended. In addition, the students discussed the possibility of refuting some of the arguments, and strategies that could have been used for refutation. Finally, the students and the teacher discussed the nature of the arguments, and the possibility of them persuading an audience, highlighting the use of emotional arguments in social contexts and the inappropriateness of its use in scientific contexts.

Table 1 – Characterization of the lessons analyzed (continuation).

Didactic sequence	Lessons	General Context	Main Remarks
Chemical equilibrium	L10	Carrying out the experiment involving the heating of the system containing nitrogen dioxide (NO_2) and dinitrogen tetroxide (N_2O_4). Construction, by the students, of models to explain the phenomenon observed (change of color of the system in response to temperature changes).	Before carrying out the experiment, Emma explained the formation of NO_2, and showed the characteristics of the substance that was in the sealed test tube (NO_2 gas), also requesting the generation of hypotheses for the procedures to be carried out, that were later discussed. The students worked in groups, seeking to come up with a model to explain experimental findings.
	L11	Rediscussion of the experimental goals linked to the experiment involving NO_2 and N_2O_4. Continuation of the creation of the models in the groups, and presentation of the models of each group to the whole class.	During the group discussions, Emma asked the students about the codes of representations used in their models and the justifications for the model as presented. In so doing, she resumed the experimental observations and asked the students about how they would interpret such findings.
	L12	Discussion of the models expressed by the students groups for the NO_2/N_2O_4 system, taking up the experimental observations and their relationships to the models. Carrying out of the stage evaluation of the models constructed in lessons 7 and 8, from analysis of the reaction between potassium chromate (K_2CrO_4) and potassium dichromate ($K_2Cr_2O_7$) in acid solution.	Initially, the discussions were focused on the core question: why was there N_2O_4 in the system at room temperature? Thus, Emma asked the students to make use of their models to answer this question and she resumed the experimental observations, seeking to help them to interpret these findings from a scientific point of view.
	L13	Presentation and discussion of the new or modified models to explain the reaction between the ions CrO_4^{2-} and $Cr_2O_7^{2-}$. Presentation of the concept of reactions in a state of equilibrium, listing observations, discussions, and explanations for the phenomenon as addressed in L10, L11 and L12.	Emma asked the students to pay close attention to similarities and differences between the different proposals, during the groups' presentations of the models, and to criticize the models proposed by the other groups, highlighting their limitations. At the end of the lesson, Emma gathered all the aspects discussed and presented the concept of reactions in a state of chemical equilibrium, stressing that she was only summarizing the ideas that the students had constructed during the lessons.

Other data was collected from interviews with the teacher. These interviews occurred: after the planning of the didactic sequence related to thermochemistry; during the planning of the didactic sequence on argumentation; after the application of a modelling-based didactic sequence involving chemical equilibrium. All interviews had the intention to look into if, and how, the teacher planned to insert argumentation as a constituent element of the classes, and also if, and how, she established a link between her actions in the classroom and any issue related to argumentation.

Data analysis

In Ibraim and Justi (2018), we produced an analytical tool based on the literature (e.g. Driver et al., 2000; Simon et al., 2006) which identifies teaching actions that may favor argumentation in classrooms. Following, we increased the analytical tool from an empirical study (Ibraim, 2018). When so doing, the actions were created or changed from reflective processes concerning the actions listed in the previous tool and in the light of the aspects discussed by Yilmaz *et al.* (2017). We have also realized that some of the original names assigned to the actions were not very clear about their characterizations. In this case, we have decided to adapt the name, with the addition of elements that help the reader to understand how a given action is actually performed. For example, with regard to the action *to encourage debate (through role play)*, originally presented in Simon *et al.* (2006) and mentioned by Yilmaz *et al.* (2017), we consider that, on the one hand, it is quite wide in scope and does not actually present evidence of how teachers could effectively encourage their students to discuss arguments. On the other hand, it is restricted to situations in which there is simulation of roles, something not always present in situations focused on the teaching of scientific curricular content. For this reason, we have changed the name to that of *encouraging the student to evaluate an argument or a claim expressed by the very student or by a colleague*, because it is made quite explicit that the teacher encourages the students to participate in the debate, based on assessment of their arguments or arguments expressed by colleagues in any situations. Such a change allows a distinction to be made from other events that happened at moments when the teacher encourages debate, for example, based on the action *to request student to contrast different interpretations for a given idea.*

Then, at a later moment, on using the modified list of actions as a category system for analysis of our data, we identified that it was not enough to characterize the variety of actions carried out by the teacher on leading the different types of didactic sequences. This meant that other categories arose from the empirical data. This process of creation of categories is illustrated for the action *to get the student involved in a reflective process about how to evaluate evidence presented when facing a claim* (Table 2). This action was identified in the dialogue between the teacher and the students during the lesson after the mock trial on the possible responsibility of fast-food chains for health problems in their consumers (L9).

Table 2 – Excerpt of a dialogue related to involvement of the students in reflective processes on how to evaluate evidence.

Speaker	**Transcription**
Emma	(The group said that) ‘It is well known that people should follow a balanced diet. Thinking about this, should the companies be held responsible? No! Because ‘it is well known that people should have a balanced diet’. Do you see this as a good argument?
David	No!
Sarah	No!
Emma	But why?
Lily	Not everyone has access to this type of information.
Emma	Not everyone has access to this type of information. Do you agree with Lily?
Jessica	However, if the person does not have access to this type of information, the same person shall not have access to fast-food!
Sarah	No?! Yes, they will!
Megan	People may even know that they need a balanced diet but do not know what a balanced diet is.
Emma	They may have no information about nutrition. It is complicated when we talk like this: This is common knowledge, everyone knows about this. Whenever we set out from this assumption that everyone knows about it, we may incur an error. This is because then we stop explaining the idea, as we start out from the principle that everyone knows, everyone understands.

In this discussion, based on questioning, Emma sought to get the students involved in thinking about the reasons for the evidence shown (the fact that it is common knowledge that everyone shall follow a balanced diet) being very frail to sustain the claim the fast-food chains should not be held responsible for the consumers' health problems. In this case, the teacher not only asked the students to evaluate the pieces of evidence, but also helped so that they could think about the reasons why that was not good evidence faced with the issue being discussed. For this reason, we conclude that this event must not be categorized based on the actions listed by the literature that involve the evidence element, and have set up an action that adequately describes the content and the intention of the teacher's action. Thus, events like this one were classified as g*et the student involved in a reflective process about how to evaluate evidence presented when facing a claim.*

Last but not least, considering the importance of explicit discussions about argumentation for the development of students' knowledge about science (McNeill & Berland, 2017; McNeill & Knight, 2013; Osborne, 2016), we also propose actions that concern thoughts about the argumentative process, such as those of *getting the student involved in a reflective process about justifying a statement based on available evidence* and *getting the student involved in a reflective process about the construction of an argument, an alternative theory, a counter-argument, or a refutation, considering the persuasion of an audience.* Finally, other actions that have not been listed in the literature related to the definition of the basic elements of an argument (for example, *define and/or exemplify the concept of evidence)* were added to our categories.

The processes as described allow the identification and the characterization of a set of actions that have mixed origin. Some came from the literature (with or without changes in wording), while others came from the empirical study here discussed, and a third group was theoretically proposed. We consider that, by using this set of actions to analyze the expression of teachers' actions, we shall be able not only to characterize their teaching practice in terms of favoring the occurrence of argumentative situations in classrooms and carrying them out, but also to discuss the elements of knowledge within the KTAtA model. Besides that, during the analysis, we realized that some actions made similar contributions for the teaching process involving argumentation. For this reason, we have divided the set of actions into four core topics:

- *Support*, involving teacher's actions that help, or create environments favorable to, the occurrence of argumentative situations.

- *Process*, related to teachers' actions that encourage students' involvement in the process of argumentation, in terms of justifying or assessing statements based on any available evidence; or persuasion of an audience with regard to the validity of the viewpoint defended, which involves the presentation of arguments, counter-arguments, alternative theories and refutations.

- *Structure*, considering the teachers' actions aimed at explanation, presentation, or exemplification of elements of the argumentative process. Such actions are related to teaching in the conceptual dimension of argumentation, and aim at contributing in a way that allows students to understand both the basic elements of an argument (evidence, justification, and claim) and the argumentative skills (to argue, to produce alternative theories, to counter-argue, and to refute).

- *Function*, referring to teachers' actions with regard to the involvement of students in metacognitive processes, seeking to contribute to get them to understand the functions of argumentation in terms of justification or evaluation of knowledge statements in the light of available evidence; or persuasion of an audience with regard to the validity of the standpoint as defended.

Therefore, the current study means a new look at the data discussed in Ibraim (2018) and Ibraim and Justi (2018) which required a systematic revision of the analytical tool and its following simplification (from 47 actions (Ibraim, 2018; Ibraim & Justi, 2021a) to 27 (Table 3)). Such a simplification resulted from our understanding that some actions could be merged with each other without compromising their meanings and their contribution to teaching involving argumentation. Thus, the use of less categories of analysis makes it possible to both discuss the identified actions in a more objective way and relate them to the topics.

Concerning the actions shown in Table 3, we point out that:

- We recognize that there are differences between argumentation and explanation, which have been the subject of lengthy discussions in the literature (e.g. Berland & McNeill, 2012; Osborne & Patterson, 2011; Reiser, Berland, & Kenyon, 2012), and that these refer to distinct epistemic functions. However, we agree with Berland and McNeill (2012) in relation to the facts that (i) these practices are complementary and synergetic, and (ii) actions of teachers and students do not need to necessarily be an accurate representation of the philosophical definitions of the scientific practices to which they relate to. Therefore, we have decided to represent the teacher action related to the request for justification, an element related to the explicit statement of the reasons why evidence supports a claim (Jiménez-Aleixandre, 2010), together with a request for an explanation, linked to the use of observations, laws, theories, as premises to shed some light on the issue to be explained (Osborne & Patterson, 2011). By so doing, we also take into account that, in science classrooms, the distinction between these elements is not easy, as this is conditional on the situations where there is interaction between the teacher and the student(s). In addition, in classrooms, especially when there is a focus on learning scientific curriculum content, the presentation of justification or explanations depends on the degree of uncertainty that the students or the teacher have assigned to a statement or an interpretation of the phenomenon – which can vary during the teaching-learning process.

- In the actions related to arguments, we include the possibility that they are related only to the claim because, in science classrooms, some of the students' utterances cannot be considered as structured arguments, even though they do contribute to the discussions involving argumentation.

The set of actions presented at Table 3 was used as an analytical tool to investigate our research question, that is, each of the actions was used as a category of analysis. Before this, however, we made sure (by means of a process of triangulation between researchers) that they were in compliance with the five essential criteria so that categories may be considered appropriate. According to Merriam (2009), categories of analysis should be: (i) responsive, which means they must be compliant with the purpose of the research project; (ii) exhaustive, which means that they include all relevant data; (iii) mutually exclusive, which means that each data unit can be placed in only one category; (iv) sensitive to data, which means that the name of the category gives some idea of its meaning or nature; and (v) conceptually congruent, which means that all the data as characterized are at one same conceptual level.

Following the validation of the categories of analysis, we carry out a new reading of the case study, seeking to identify events in the lessons that were related to the actions that contribute to science teaching involving argumentation. In this regard, the following events were considered: the speech of the teacher, or parts thereof; and instances of dialogue between the teacher and the students (Christodoulou & Osborne, 2014). The purposes of the rereading of the events were: to identify and characterize the actions as done by the teacher within the regular teaching contexts; and to check if those actions created based on the case study gave an adequate and appropriate description of the event analyzed.

Table 3 – Actions that contribute to science teaching involving argumentation.

Topics	Actions that contribute to science teaching involving argumentation
Support	To encourage listening to ideas stated by other people.
	To encourage participation in discussions, and expression of ideas by the students.
	To request clarification of details of an idea presented.
	To request the student to contrast different interpretations for a given idea.
	To encourage the student to take up a position.
	To identify and/or value different analyses of the problem issue.
	To request the generation of a hypothesis for the problem being discussed.
	To make a question based on the student's idea, or reconsider such an idea, with the aim of getting other students involved in the discussion.
Process	To request the presentation of evidence (arising from data, observations, or information).
	To request the evaluation of evidence.
	To present evidence (arising from data, observations, or information).
	To request the presentation of a justification or explanation.
	To present and/or emphasize a justification or explanation.
	To encourage the construction of an oral and/or written argument or claim.
	To encourage the construction of an oral and/or written subsequent argument (alternative theory, counter-argument or refutation).
	To request clarifications about an argument, an alternative theory, a counter-argument, a refutation, an explanation or a student's claim.
	To construct an oral and/or written argument or claim.
	To construct an oral and/or written subsequent argument (alternative theory, counter-argument or refutation).
	To encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague.
	To evaluate the argumentative process, an argument or a claim.
Structure	To define and/or exemplify the concept of evidence.
	To stress the importance or the role of evidence in the construction and rebuttal of an argument.
	To define and/or exemplify the concept of justification.
	To define and/or exemplify the concept of argument, alternative theory, counter-argument, or refutation.
Function	To get the student involved in a reflective process about how to evaluate evidence presented when facing a claim.
	To get the student involved in a reflective process about justifying a statement, based on available evidence.
	To get the student involved in a reflective process about the construction of an argument, an alternative theory, a counter-argument, or a refutation, considering the persuasion of an audience.

We made a detailed analysis of the events identified based on the case study, and then calculated the frequency of occurrence of each such action in the 13 lessons analyzed. This calculation was made considering the total actions as observed in that lesson (100%) and the percentage corresponding to each specific action. This was done seeking to make evident, and present to the reader, a panorama of the occurrence of the actions, and the identification of the lessons in which they were most frequent, which backs up the discussions concerning each of the topics of the actions as presented in this paper. Throughout the discussion, we have presented excerpts of the case study which illustrates actions taken by the teacher.

Finally, based on the analysis of the actions manifested by the teacher, we sought to identify possible relationships with the other dimensions of teaching knowledge mobilized by the teacher when she is leading different types of didactic sequences. For that, we used as reference for the analysis the elements proposed by Shulman (1986, 1987) and Magnusson and collaborators (1999), which were previously mentioned.

The whole analysis was triangulated between different analysts, as a way to make sure of internal validity (Cohen, Manion, & Morrison, 2011; Merriam, 2009). Thus, independently, each of the authors analyzed the data, after which the results were compared and discussed until a consensus was reached regarding the classification of data into categories. In addition, we carried out a triangulation of data, using the data obtained in interviews with the teacher, to identify her real goals at some points within the teaching situations. In this way, we validate and assign reliability to our analysis with regard to the actions that contribute to science teaching involving argumentation as identified and characterized in the events analyzed.

RESULTS AND SPECIFIC DISCUSSIONS

The frequency of the actions that contribute to science teaching involving argumentation as shown by the teacher in each of the 13 lessons analyzed is presented in Table 4. Aiming at providing the reader with a clear characterization of the actions, next we discuss and exemplify all of them.

Table 4 – Actions that contribute to science teaching involving argumentation as performed by the teacher during the 13 lessons analyzed.

Topics	Actions that contribute to science teaching involving argumentation	Frequency[2]												
		L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13
Support	To encourage listening to ideas stated by other people.	4,5	3,1			4,3				4,0		8,3		
	To encourage participation in discussions, and expression of ideas by the students.	36,4	15,5		9,1		5,0	14,3		4,0	16,7	16,6		
	To request clarification of details of an idea presented.					8,6	5,0						11,1	5,3
	To encourage the student to take up a position.	4,5		22,2	9,1	8,6	10,0			8,0			7,4	5,3
	To request the generation of a hypothesis for the problem being discussed.				27,3						13,3	8,3	3,7	
	To make a question based on the student's idea, or reconsider such an idea, with the aim of getting other students involved in the discussion.	13,6				4,3				4,0		8,3	7,4	
Process	To request the presentation of evidence (arising from data, observations, or information).	13,6				17,2	10,0				9,9		7,4	10,6
	To request the evaluation of evidence.	4,5	15,5		27,3	8,6	10,0				16,7		7,4	15,9
	To present evidence (arising from data, observations, or information).	13,6	22,8	44,4	9,1	17,2	10,0				23,4	24,9	18,5	15,9
	To request the presentation of a justification or explanation.	9,1	15,5	11,1	18,2	17,2	15,0				13,3	16,6	7,4	15,9
	To present and/or emphasize a justification or explanation.		9,3	11,1		4,3	5,0						3,7	
	To encourage the construction of an oral and/or written argument or claim.		9,3				10,0						11,1	
	To encourage the construction of an oral and/or written subsequent argument (alternative theory, counter-argument or refutation).									8,0				

[2] As we have shown the results rounded to one decimal place, the total actions shown in any one lesson may not be exactly 100%.

Topics	Actions that contribute to science teaching involving argumentation	Frequency[2]												
		L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13
	To encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague.			11,1			10,0		16,6	8,0		8,3	11,1	31,8
	To evaluate the argumentative process, an argument or a claim.						10,0	14,3		20,0		8,3	3,7	
Structure	To stress the importance or the role of evidence in the construction and rebuttal of an argument.		6,2			4,3		28,6			3,3			
	To define and/or exemplify the concept of argument, alternative theory, counter-argument, or refutation.							14,3						
Function	To get the student involved in a reflective process about how to evaluate evidence presented when facing a claim.								33,2	20,0				
	To get the student involved in a reflective process about justifying a statement, based on available evidence.		3,1					14,3	16,6	8,0				
	To get the student involved in a reflective process about the construction of an argument, an alternative theory, a counter-argument, or a refutation, considering the persuasion of an audience.							14,3	33,2	16,0				

The action 'to encourage listening to ideas stated by other people' was shown by the teacher at those moments when the students were dispersed or all talking at the same time, especially at the start of the discussions (see examples in Tables 8 and 11, as discussed later). Even though we do acknowledge and accept the importance of this action for argumentative processes, as students need to listen to colleagues' ideas so that such ideas can be considered in their arguments (Simon et al., 2006), in the situations as analyzed we notice that the expression of this action was related exclusively to the organization of discussions, representing an evidence of teacher's pedagogical knowledge.

At the moments when a student came up with an idea or a question which helped to kindle discussion, instead of encouraging students to listen to the colleague, Emma went back to the discourse of the student or raised another question based on it. In this way, she showed the action 'to make a question based on the student's idea, or reconsider such an idea, with the aim of getting other students involved in the discussion'. For example, in L1, Noah said that, when only the wick was burnt, the amount of energy produced was much less when compared to the burning of the whole candle. As part of the class had not heard what Noah had said and that was an important piece of evidence for the discussion of the role of wax in the candle, Emma returned to the student's idea, presenting it in question form for the whole class. To involve students in the discussion about evidence is coherent with the teacher's knowledge related to inquiry, which means an orientation toward teaching science following by Emma, based on her preview teaching experience.

As shown in Table 4, the action 'to encourage participation in discussions, and expression of ideas by the students' was shown by the teacher in L1, L2, L4, L6, L7, L9, L10 and L11. The issue discussed in L1 allowed students to express their ideas based on their daily experiences. This contributed so that the teacher could add value to their participation. In other cases, this action was observed in those moments where Emma requested the participation of students without the intention of assessing the answers, which happened at the start or at the end of lessons. For example, after listing the students' answers to the question being discussed on the board, the request made by the teacher resulted in the statement of a new idea by John and the raising of a doubt by Sarah, which led to a counter-argument from John (Table 5). Because of this, we suggest that this action could be regarded as a kind of 'trigger' to get students involved in argumentation, as they tend to be more comfortable stating their ideas when they feel that the teacher is not expecting a correct answer.

Table 5 – Example of manifestation of the action 'to encourage participation in discussions, and expression of ideas by the students.

Speaker	**Transcription**
Emma	These were the main ideas in the answers. I would like to know who thought of something else.
John	I think it is like this because coal is porous. You start blowing and force the oxygen into it. Then, already hot, it is prone to catching fire.
Sarah	I answered considering contact surface. However, I found one thing very strange: when you set fire to the coal, you need to stay there a long time, blowing, so that the fire actually ignites. It takes a long time.
John	It is just like gasoline and the candle. The candle would take much longer. It is to do with the material.

The action 'to request clarification of details of an idea presented' was shown by the teacher as a way of testing the students' learning, or their understanding of scientific concepts, which occurred at the times when she considered it necessary for them to express their answers better. For this reason, it was shown in discussions regarding aspects of thermochemistry (see examples in Table 8, to be discussed later) and aspects of chemical balance (see examples in Tables 7 and 9, to also be discussed later), where the teacher went back to scientific concepts, or discussed them in greater detail.

In general, during discussions, especially those involving the closing of conceptual discussions, Emma came up with alternative answers for a question and then encouraged the students to take a position regarding these. For this reason, the action 'to encourage the student to take up a position' was shown most significantly in L3, L5, L6, and L12 (Table 4). In addition, students taking a position on something could help them to get involved in argumentation from the use of evidence and justification to support their positions (Jiménez-Aleixandre & Erduran, 2008). However, for this to happen, it is necessary that the teacher encourages actions concerning these elements, as even though they take a position themselves, in most cases the students do not present the reasons for this, as can be seen in Table 6.

Table 6 – Example of manifestation of the action 'to encourage the student to take up a position'.

Speaker	**Transcription**	**Teacher's actions**
Emma	Guys, let's now discuss what is happening. When we blend in the two reagents, do you think there is a reaction or not?	To encourage the student to take up a position.
Students	Yes, there is.	
Emma	But how can you know that there is a chemical reaction?	To request the presentation of evidence (arising from data, observations, or information).
Lily	Because, you know, there are two solids, and they form a liquid without the addition of heat...	

The action 'to request the generation of a hypothesis for the problem being discussed' was shown by the teacher in those lessons where the students were doing experiments (L4, L10, L11 and L12). She specifically requested that they generate their hypotheses before carrying out the experimental procedures and, from that moment on, aimed the attention of the students towards the evidence that could either validate or refute their hypotheses. In these cases, the students could not give random responses, by just expressing any idea, as the answer needed to be coherent with the discussion and suitable for evaluation. In the excerpt presented in Table 7, the intention of making the students generate a hypothesis is clear because after Daniel had thought of a hypothesis, Emma asked the students about how they could assess the validity thereof, which is related to the use of evidence to either support or reject a hypothesis.

Table 7 – Example of manifestation of the action 'to request the generation of a hypothesis for the problem being discussed'.

Speaker	Transcription	Teacher's actions
Emma	I shall now place this tube (referring to the test tube containing NO_2) in ice. What do you think will happen?	To request the generation of a hypothesis for the problem being discussed.
Sarah	It will condense.	
Emma	It will condense.	
Daniel	The reaction inverts.	
Emma	So, the reaction inverts in which direction?	To request clarification of details of an idea presented.
Daniel	When you warmed it, it became a product; now it becomes a reagent.	
Emma	Why do you think that?	
Daniel	Because you heated the lead nitrate and it decomposed.	
Emma	How can I know if the Daniel's hypothesis is indeed valid?	Request the presentation of evidence (arising from data, observations, or information).

The action 'to request the presentation of evidence (arising from data, observations, or information)' was shown by Emma with the intention of making the students pay attention to the phenomenon as investigated, helping them recognize the occurrence of a chemical reaction in the systems (as shown, by way of example, in Table 6). This happened in L1 and L10, where the teacher started a discussion about a given scientific content. In L5, L6, L12 and L13, the expression of this action had the intention of making the students return to the evidence or concepts discussed in previous classes, to evaluate the understanding of the students, so that the conceptual discussions may proceed. In the excerpt of Table 8, the teacher and the students returned to the evidence of the occurrence of a chemical reaction within the system they had investigated in L4. Directing attention to the evidence of a chemical reaction at this moment in time was important so that the students could recognize that the system with which they were working was different from other systems that they had studied previously, where physical transformations occurred.

Table 8 – Example of manifestation of the action 'to request the presentation of evidence (arising from data, observations, or information)'.

Speaker	Transcription	Teacher's actions
Emma	But how can you know that there is a chemical reaction?	To request the presentation of evidence (arising from data, observations, or information).
Lily	Because, you know, there are two solids, and they form a liquid without the addition of heat…	
Emma	Guys, please pay attention to what Lily is saying. Two solids…	To encourage listening to ideas stated by other people.
Lily	... turn into one liquid, without the person adding any source of energy. They react, thus becoming a liquid.	
Emma	So, a liquid is being formed, which is a piece of evidence in itself.	To define and/or exemplify the concept of evidence.
Emma	And this liquid is a piece of evidence of what?	To request the evaluation of evidence.
Students	That things have changed.	
Emma	What has changed?	
Students	The substance.	
Emma	The constitution. If the substance has changed, then so has the constitution. What is this?	To request clarification of details of an idea presented.
Students	Reaction.	
Emma	Chemical reaction. What other evidence that there has been a chemical reaction could you mention?	To request the presentation of evidence (arising from data, observations, or information).
John	Gas has been given off.	
Daniel	The temperature has changed.	

With regard to the action 'to request the evaluation of evidence', this was shown by the teacher at some moments after the students came up with evidence (as shown in Table 8), or on going back to the evidence mentioned by the students and/or by the teacher, throughout the discussions. In these cases, Emma requested the analysis of the evidence as a way to evaluate if the students recognized the piece of data presented as effectively being a piece of evidence for the claim under discussion. Also, she expressed their knowledge about the concept of evidence and their knowledge about a strategy that contributes to teaching about basic elements of an argument and involves the student in reflection on data.

The action 'to present evidence (arising from data, observations, or information)' was taken by the teacher in all situations focused on scientific aspects. We realized that Emma showed this action when she felt that the students needed certain bits of information so they could proceed or, also, get engaged in a new discussion or in the investigative process. In addition, the evidence showed by the teacher was strongly linked to the concepts or aspects of chemical language, that is, with information that the students were unable to construct through interpretation of data alone. This was the case mainly in the lessons where Emma discussed experiments with the students (L1, L2, L4, L10 and L12), stressing the data on the constitution of products of chemical reactions and their characteristics. For example, in L2, she presented data regarding the composition of wax, which amounted to evidence to the claim that it is inflammable:

> *"This candle is made of wax, which is not a substance but rather a material, as wax is not pure, it is a mixture containing many different substances. The main constituent part of wax is what we know by the name of icosane, a substance with 20 carbon atoms. Have we ever discussed any other molecules containing only carbon and hydrogen? Sure: CH_4, methane, do you remember now? [...] Hydrocarbons are used as fuel gases. If those hydrocarbons burn, could the hydrocarbons in candles also burn? Yes, it is quite possible that they will also burn."*

At other moments, especially in lessons after experiments have been carried out (L5, L11 and L13), Emma quoted evidence when she returned to the data discussed in previous lessons. As the lessons were on Tuesdays and Wednesdays, discussions could be continued after one or six days. In this last case, the manifestation of this action was important, so that the students would recall the evidence that had been discussed in previous lessons and could use them as support for the conclusions that they would construct throughout the discussion. Emma also used evidence in lessons where there was the closure of discussions about the phenomena investigated (L3, L6, L11 and L13), thereby supporting the establishment of relationships between scientific explanation, evidence, and the phenomenon observed. In this sense, this action is related to the teacher's knowledge of students' understanding of science because it shows the recognition of the students' difficulties in following conceptual discussions.

The action 'to request the presentation of a justification or explanation' was shown by the teacher in all lessons related to scientific knowledge. Here we note that she asked the students to come up with justification and to explain how they linked evidence to scientific claims based on the use of their prior knowledge, especially at the start of experimental discussions (L2, L4 and L10) (see example in Table 9, to be discussed later). At these moments, the claims were still largely open because, even when the students had made a claim, they showed that they were not convinced that this was appropriate.

At other points in time, Emma's expression of such an action seemed to be more related to requests for explanations, as these were shown at moments when the claim was more consensual, or when Emma and the students were discussing about how the phenomena investigated could be interpreted. For example, during a discussion with one of the groups in L5, the students informed the teacher that the temperature of the system involving NH_4SN and $Ba(OH)_2$ had declined, and that they had observed this fact through the decrease of the value shown on the thermometer. So, Emma asked what was happening to the mercury inside the thermometer and the students replied that it was contracting. At that moment she asked: "*Why does mercury contract?*". In this case, as the claim regarding contraction was not under discussion, the intention of the teacher was that the students could think about submicroscopic aspects and come up with an explanation linking the energy variation of the system with the contraction of the mercury.

The action 'to encourage the construction of an oral and/or written argument or claim' was shown by the teacher mainly at the end of the lessons, after a request for construction of an argument, as a way for the students to resume discussions made during the lessons. For example, in L2, after discussions about evidence that wax was a fuel for the reaction of burning of a candle, the teacher encouraged the students to come up with an argument based on the following command: "*Guys, has the problem of the candle been solved? Now, you shall do the following: you shall write this answer. Think about how many things we have discussed... you shall bring all this together and write an answer in your notebook*". The facts that the request for the construction of an argument occurred in the form of setting a task to be done at home and that the arguments were not taken up in the following lessons contributed to these not being taken as objects of study and discussion during the lessons, which could have favored the expression of the action 'to encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague' more frequently during the lessons (Table 4).

The action of 'to encourage the construction of an oral and/or written subsequent argument (alternative theory, counter-argument or refutation).' was shown only in L9. During the discussions about the arguments presented in the mock trial, the teacher encouraged the students to construct a rebuttal of the idea that they had presented. "*Returning to the argument of social exclusion, how could you rebut this? The person replied: 'Ah, but people feel excluded, as not everyone has the means to buy a snack from Fast Burger[3]"*. In this case, she used the strategy of mock trial to teach about argumentative skills based on the experience of the students in elaborating this kind of argument.

In the light of observations about the teacher's requests for the students to construct arguments, the action 'to encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague' was taken by Emma especially with regard to a request for evaluation of claims made by the students regarding the phenomena investigated (which occurred in L3, L6, L8, L9, L11, L12 and L13, Table 4). As this action was taken on many occasions during L13, we analyzed the moments when this happened, and confirmed that they corresponded to the moments of socialization of the models by the groups, when Emma asked the other students about whether they agreed with the model expressed by their colleagues and the reasons for this. For example, in a discussion with a group of students as part of L13 (Table 9), Emma encouraged the other members of the group to evaluate the statement made by one of the colleagues, in an attempt to make the other students state their own ideas.

Table 9 – Example of manifestation of the action 'to encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague'.

Speaker	Transcription	Teacher's actions
Emma	When you say this will be a cycle, then it will work like this: chrome reacts with acid and forms a product, then this product reacts and forms chromate? Is that what happens? Does one happen and then the other? Or does all this happen at the same time?	To request clarification of details of an idea presented.
Oliver	It is at the same time, because the color does not change.	
Emma	The color does not change. This is an interesting observation. Oliver, why does the color not change?	To request the presentation of a justification or explanation.
Oliver	I think that if there were a reaction... if the $Cr_2O_7^{2-}$ reacted and went back to the form of $Cr_2O_4^{2-}$, if it went back to form $Cr_2O_7^{2-}$ and took a long time, then there would have to be a change in color, as the concentration would keep changing.	
Emma	(Pointing to Oliver) That is a good justification to say that not everything happens, and then the reagents return? Look into what he said. What do you think about what Oliver said?	To encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague.
James	If it was just a matter of passing from reagents to products, there would surely be a change of concentration.	
Emma	So, if we waited for everything to pass, to then return, what would happen then?	
James	There would be a greater concentration and there would be one color only.	

In the lessons concerning the mock trial, we noticed that Emma showed the action 'to encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague' with a different intention. In these cases, she encouraged them to evaluate the relevance and the validity of arguments, considering the situation in which they were announced (meaning if they complied with the original target of trying to convince others about the standpoint defended), or the structure of the argument (see example in Table 12, discussed later).

The action of 'to evaluate the argumentative process, an argument or a claim' was carried out by Emma mainly at the end of the lessons, when she presented a summary of decisions made, as can be seen in her speech at the end of L2 (Table 10). In this case, on evaluating the argumentative process and the explanations generated during the lesson, Emma stressed that the experimental observations made by Daniel and Harry were strong evidence to support that wax is inflammable, also stressing the role of evidence in the construction of arguments.

Different from what happened in situations focused on the teaching of scientific curricular components (L2, L6, L11 and L12), in L7 and L9, Emma stressed discussions on argumentation, seeking to contribute so that the students could learn now to evaluate and construct arguments that are harder to be rebutted (Table 11). In L9, based on an argument presented in the mock trial, the teacher got the students involved in thought about the construction of arguments, to make them think about the need for the argument to be directly linked to the question being discussed. After the answers given by the students, she then evaluated the argument as presented. In this case, the assessment had the intention to close the process of analyzing the idea as presented.

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[3] Use of a fictitious name to avoid the identification, and hence advertising, of the brand.

Table 10 – Example of manifestation of the action 'to evaluate the argumentative process, an argument or a claim' in L2.

Speaker	Transcription	Teacher's actions
Emma	When we put all this evidence together…it is clear that we had the possibility that the wax could be evaporating, just evaporating. However, if the wax only evaporates and does not burn, then there would have been production of the same amount of energy that would have been produced just by the wick. If there was just the wick burning, the wick would be there just to delay the flame a bit. Especially in the case of the experiment that Susan made, if it is the wick that burns, and if there is wax in both cases, then why would one candle be thicker or thinner if the thickness of the wick is the same? And the thicker candle, even having the same kind of wick inside, took longer to burn. If we consider that the same amount of wick was burning in both cases, why did the thicker candle last longer? This is because what is really happening is the process of burning of wax.	To evaluate the argumentative process, an argument or a claim.
Emma	The experiments carried out by Daniel and Harry were very good experiments for us to visualize this phenomenon: on putting the candle in the flame but without the wick, you see flames rising. This is very strong piece of evidence that what is burning is actually the wax. Putting an already-burnt match in the wax and then in the flame makes the match ignite again, which is also a very strong piece of evidence that it is the wax that is burning. All these observations show that the most important combustible element in a candle is actually the wax.	To stress the importance or the role of evidence in the construction and rebuttal of an argument.

Table 11 – Example of manifestation of the action 'to evaluate the argumentative process, an argument or a claim' in L9.

Speaker	Transcription	Teacher's actions
Emma	Another argument that was used involved the snack at Fast Burger, with the advertising campaigns promoting a bit of social exclusion, as not everyone has the financial means to afford the snack. This means that they could feel excluded. This was an argument raised by the group that defended the responsibility of the fast-food companies. First, we had to think of the relevance of the argument. Is it related to health problems? To the obesity issue?	To get the student involved in a reflective process about the construction of an argument, an alternative theory, a counter-argument, or a refutation, considering the persuasion of an audience.
Ethan	There is no connection.	
Emma	This means that they are moving away from the focus, which was what the jury said. Some of the arguments were a bit detached from the focus of discussion.	
Tracy	I think that this could even give rise to a wider discussion, because of the discussion on preservatives... sodium is used in all industrialized products, and not only for fast food. Many of our arguments were taken in general...	
Sarah	...processed food in general.	
Emma	Did you understand what the girls were saying?	To encourage listening to ideas stated by other people.
Emma	What the girls said was very interesting. On many occasions, the arguments were presented, but there was no clear link to the fact that this was fast food. So, some information referred to processed food in general. There was a need to establish this link and say that fast food only uses processed foodstuffs. Then, some things even got to be said in this regard, but initially most of the arguments had no link at all. This is a point that you identified very well.	To evaluate the argumentative process, an argument or a claim.

The action 'to define and/or exemplify the concept of evidence' was only shown by the teacher on two occasions, when she highlighted that an observation made by the students was a piece of evidence within that context (as shown, by way of example, in Table 8). On the other hand, the action of 'to stress the importance or the role of evidence in the construction and rebuttal of an argument' was shown by Emma at least once in each of the four didactic sequences (Table 4). In general, the teacher took this action on stressing that data presented by the students were evidence to the claims that were in discussion (as exemplified in Table 10). In these cases, the emphasis given by the teacher had the purpose of highlighting the reasons to believe in statements or explanations as generated. However, in L7, on discussing with the students about how to construct evidence based on a set of data, Emma stressed that the role of evidence is that of justification:

> *"You have a lot of information and data, and many ideas, but you have to think about which shall be chosen to reinforce and give support to your justification. And it is very important to also consider that this justification needs to have good grounds,*

integrating such data and information. This is what is known as evidence. So, you use something, select it, and then bring it into your idea to reinforce the justification. This is a piece of evidence for a statement".

In this excerpt, we can see that Emma does not clearly state the meanings of the core terms, evidence and justification. In spite of this, she manages to convey to the students that evidence is related to data, and that they should articulate this data to the claims, which means elaborate claims related to the viewpoint that they shall defend.

The action 'to define and/or exemplify the concept of argument, alternative theory, counter-argument, or refutation' was shown by the teacher only once in L7 and L9 (Table 4), both linked to the concept of refutation. In L7, Emma, gave an example of the meaning of refutation and its role in argumentation: "*Raising an argument against something. Contest. This is you going against someone else's idea. So, the group will have a moment, during the reply, where they will dispute the idea that the other person has presented.*" The attention given by the teacher to the meaning of refutation was linked to the instructions on the goal of the mock trial activity, in which the students would need to come up with replies to the arguments constructed by the other group. On the other hand, in L9, on discussing with the students about the argumentation that occurred in the mock trial, Emma ended the discussion by establishing that: "*Argumentation is also in strengthening your idea and being careful not to use anything that could go against it, which cannot be easily rebutted.*"

The action 'to get the student involved in a reflective process about how to evaluate evidence presented when facing a claim' was shown by the teacher exclusively in L8 and L9, during the discussions about how to use data so that they may be more robust and specific to give support to the viewpoint defended. In the dialogue (Table 12), Emma discussed one of the arguments used by some students. Based on the request that the group should evaluate the statement, the teacher encouraged them to think about the criteria that could be used for the evaluation of evidence and how this could contribute to make the argument stronger. By so doing, she mobilized her knowledge about argumentation because she emphasized how to construct strong arguments face to the meaning of the elements of an argument.

The action 'to get the student involved in a reflective process about justifying a statement, based on available evidence' was carried out by the teacher exclusively in teaching situations related to the mock trial (Table 4) after discussions on the importance of justification to explain the relations between data and the viewpoint to be defended. Emma had the intention of making the students think of how to come up with justification seeking to construct arguments that are more solid. For example, in L7, she favored the students' thinking about the construction of evidence and then, after a brief explanation of the procedures of the activity, arising from a query raised by John, she continued to do this based on an example from the history of chemistry. In this example, Emma showed that the same data could be used in a different way by scientists, which means that it is possible to produce different justification, that is, to use one same set of data to give support to different claims (Table 13).

Table 22 – Example of manifestation of the action 'to get the student involved in a reflective process about how to evaluate evidence presented when facing a claim'.

Speaker	Transcription	Teacher's actions
Emma	'Because a scientist said that Fast Burger was not bad for you'. What do you think about this argument?	To encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague.
Daniel	I would ask if it were from a reliable source.	
Emma	But you will not be allowed to interrupt at any moment. You shall analyze the arguments and see if they have valid grounds.	
Daniel	It is not valid.	
Harry	If that is the argument, it is not valid at all.	
Emma	Indeed. What are the grounds that would make the argument valid?	To get the student involved in a reflective process about how to evaluate evidence presented when facing a claim.
Jessica	Which scientist? There could be millions of scientists.	
Emma	Apart from having the participation of a scientist, and a research study behind the information, one must also think if this is data that has already been released, where it was released from, if someone wrote about this in a blog... and what weight it carries... Does that person have the technical or scientific knowledge to make this statement? In the end, everything has to be observed. Analyze this carefully, and plan how you will make this judgement tomorrow.	

Table 33 – Example of manifestation of the action 'to get the student involved in a reflective process about justifying a statement, based on available evidence'.

Speaker	Transcription
Emma	So, what I am now telling you is that you need to improve this idea. You need to improve this justification. Are you clear about what justification is? What you need to do with this argument? You need to work with consistent arguments and be able to assess what is being said based on the evidence and also have to give a good justification for everything that is being used.
John	Teacher, how shall the verdict be given?
[...]	
Emma	Guys, in the research you will carry out, the data and the information you will be able to access are the same, this is the information and data as available. This depends on the research that each person will do, but everyone has access to the same sources: books, magazines, the Internet and so on. However, how you shall use the data is a different story entirely. I shall give you an example using the history of chemistry to show how one same set of data can be interpreted in different ways.

The action 'to get the student involved in a reflective process about the construction of an argument, an alternative theory, a counter-argument, or a refutation, considering the persuasion of an audience' was also shown during the discussions related to the mock trial. In this case, the intention was that of leading the students to think about how to prepare strong arguments and rebuttals in relation to the issue being discussed. Especially in L9, Emma sought to get the students involved in thoughts on construction of arguments based on the analysis of the arguments they presented in the mock trial. However, she did not just ask them to assess the arguments made, but also tried to make them think about the reasons for the arguments as presented to be easily refuted. For example, in L9 (Table 14), she showed such an action on promoting the discussion about one of the arguments as shown in the mock trial.

Table 44 – Example of manifestation of the action 'to get the student involved in a reflective process about the construction of an argument, an alternative theory, a counter-argument, or a refutation, considering the persuasion of an audience'.

Speaker	Transcription
Emma	And if I say: I have never been to Fast Burger, never eaten there, and cannot even afford a snack at Fast Burger, not feeling in any way excluded because of this. Does this invalidate this argument?
John	I don't think so.
Tracy	This could be an exception.
Emma	An exception to what, Tracy?
Tracy	Among people who have never been to Fast Burger, and never eaten there.
Emma	But are there people like this?
Tracy and Sarah	Yes.
Emma	So, I am saying that yes, there is a way, there are arguments we must be very careful with, as they can easily be invalidated. This is an example of an argument that tries to establish an emotional appeal, but is not successful. So, anyone can refute or invalidate this argument.

This example (Table 14), like the others as presented and discussed in this section, helps the reader to perceive how the teacher's actions can be articulated to argumentation in the classroom and its relations to her PCK, or how they can be expressed during the leading of didactic sequences whose focus shall be the teaching of scientific curricular content.

GENERAL DISCUSSION

The results of this study show that, over the 13 lessons, the teacher showed actions from all four core topics: support, process, structure and function. Actions from the *support* topic are essential for the development of argumentation in the classroom, and were taken by Emma both with the intention of adding value to the participation of the students in discussions, representing her pedagogical knowledge, and to favor their positioning and attention to the ideas that were being presented by colleagues, which is related to her knowledge of teaching strategies coherent with argumentative practice. In regular classrooms, it is quite common for students to convey their ideas only to the teacher, as they feel that the teacher is the only interlocutor (Cazden, 2001). Therefore, the constant and common expression of support actions by the teacher can bring about a change in these classrooms, in a way that students cease to see the teacher as the only person to whom answers, and attention should be directed. In this sense, we consider that argumentation can be thought of as an orientation toward teaching science since it amplifies the teacher's actions in terms of student participation. In the argumentative context, the fact that students express their ideas and take up a position within discussions, as also listen to the ideas of colleagues, can, at later moments, make it possible for them to analyze evidence as presented, to think about the validity of such ideas, and to generate alternative theories or refutation. This means that actions of *support* are essential for the establishment of an argumentative environment in the classroom, seeking persuasion and criticism, as, without these elements, students may not pay attention to colleagues' ideas (Henderson, McNeill, Gonzáles-Howard, Close, & Evans, 2018) or even not consider different or divergent ideas in their statements (Ford, 2008). In addition, such actions may contribute to students' involvement in collaborative argumentative processes, in which they can address and discuss their uncertainties (Chen et al., 2019).

Even though actions of the topic *support* contribute to teaching involving argumentation, the manifestation of such actions is not, in itself, sufficient for the teacher to teach science involving argumentation. This is because teaching could be limited to the use of a dialogue approach, without progressing to argumentative discourse, where evidence is used to support the viewpoint defended or there is the explicit intention of convincing the interlocutor about the validity of the viewpoint defended (Jiménez-Aleixandre & Erduran, 2008). We highlight that the teacher contributed to the science teaching involving argumentation based on the expression of actions of the topic *process*, which are linked to the involvement of the students in argumentation, seeking the justification and evaluation of statements of knowledge, considering the evidence available or the persuasion of an audience. Because of this, we have been arguing in favor of teachers' knowledge for actions through argumentation, since this is beyond to know how to represent scientific topics (Ibraim & Justi, 2021b).

In relation to the topic *process*, we see that Emma gave greater attention to the understanding of the meaning of evidence and the use thereof, requesting the students to identify evidence for their statements and to evaluate the evidence presented by them or by their colleagues. In addition, during the lessons, she requested the generation of explanations for the phenomena as investigated, and got the students involved in the construction and assessment of arguments.

These actions also had the intention of getting the students involved in learning processes, so that they could evaluate their own knowledge. This is because, on expressing their justification, generating explanations, or evaluating the evidence used (or which could be used in support of a claim), they could reflect whether they were really understanding what was being discussed and if their interpretations were valid in that context (Jiménez-Aleixandre, 2010).

Thus, we understand that Emma contributed to the occurrence of argumentative situations with regard to the establishment of a consensus, which involves the justification element and also the evaluation of scientific statements with regard to the set of the available evidence. Argumentation in search of the establishment of a consensus involves negotiations, seeking to understand opposing points of view and also evaluating the limitations of different arguments (Chen et al., 2019; Leitão, 2000). In this regard, the contributions of the teacher were well aligned with two of the goals concerning the development of the students in relation to the use of argumentation in teaching, as proposed by Berland and Reiser (2009; 2010): *giving the phenomenon under study a meaning*, which means the production of statements and explanations about the phenomenon, and *articulating understanding*, something which would be expressed from the production of arguments. Therefore, based on actions of the topics *process* and *support*, the teacher contributed to the creation of argumentative situations seeking the establishment of a consensus about the best explanations for the scientific phenomena investigated.

In addition, some actions within the topic *process* as shown by the teacher in a frequent and consistent manner had the potential to get the students involved in situations seeking persuasion, where the subjects criticize, evaluate opposite ideas, or defend their own ideas (Berland & Reiser, 2009; 2010). For example, in over half the lessons, Emma showed actions 'to request the presentation of evidence (arising from data, observations, or information)' and 'to encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague'. In spite of this, within the context investigated, we realize that these actions were shown as a way to evaluate the students' knowledge during the teaching process or delegating responsibility of this evaluation to them. Like Sengul *et al.* (2020), we notice that the teacher have placed great emphasis on the students' understanding of scientific content, paying less attention to social interactions, especially those related to persuasion.

With regard to persuasion, we note that regular teaching contexts with the aims being the teaching and learning of scientific curricular content may not favor argumentation involving persuasion between peers, due to particularities of context. Different from what happens in science, where there is the production of new knowledge and scientists need to convince their peers of the validity of the knowledge that has been produced

(Osborne & Dillon, 2010), in the classroom environment the students deal with canonical knowledge, that has been validated and confirmed as legitimate by the scientific community (Osborne, 2014). In addition, they have access to a lot of information on the phenomena being investigated, and the content which their teacher has worked on, based on teaching materials or online search engines (Wang, 2020). Therefore, the students well know that there is a consensus answer, and that the teacher knows the explanation for the phenomenon under investigation. This could contribute to making the students lose motivation to get engaged in persuasive argumentative situations, as they can understand that it is up to the teacher to decide what is right and what is not; in other words, to validate and establish legitimacy of the scientific statements they have created.

In addition, it seems that the actions that contribute to science teaching involving argumentation as shown by the teacher had strong influence from her orientation towards investigative teaching. According to Magnusson *et al.* (1999), the orientation towards teaching science is part of teachers' PCK; they are linked to their own beliefs and knowledge about aims for teaching science at a certain level; and guide the development of other types of teachers' knowledge. Thus, we consider that the fact that Emma adopted an investigative orientation contributed for her to give value to argumentative processes that are intrinsic to investigation, to favor teaching-learning processes connected to scientific explanations, and to adopt teaching strategies (experimentation and modeling-based ones) coherent with the investigative approach and that would contribute towards the conceptual learning of the students.

Actions of the topics *structure* and *function* were shown by the teacher mainly in the didactic sequence with a focus on argumentation (the activity of the mock trial). Differently from other didactic sequences, in this case Emma had the intention of getting the students involved in an activity of discussion and debate, where they should persuade the group of judges about the validity of the positions they defended in the trial (Bogar, 2019).

The actions of the topic *structure* are related to the conceptual teaching of argumentation, which means teaching the basic elements of an argument, as well as the meaning of the argumentative skills. The fact that we have not observed any emphasis on the part of the teacher in the conceptual discussions on argumentation is coherent with what she reported during her final interview. Emma said she considered it important that the students (i) understand how an argument is constructed in terms of coherence between evidence and justification, validity, and specificity of evidence and reliability of an argument; and (ii) learn how to argue based on practical situations. She also stressed that she did not consider it important for students to learn the concepts themselves (the basic elements of an argument and argumentative skills) and that this had value for those who thought of argumentation from an analytical standpoint, such as researchers who investigate the arguments produced by students. In a nutshell, Emma believed that, for students, what was really important was to learn how to handle data, to produce coherent justification for their claims, to rebut ideas, to evaluate the validity of alternative theories. For this reason, they would not need to learn the formal concept of each of these elements, or even the names of some of them.

In more recent models of PCK, the beliefs held by teachers have been acknowledged as being amplifiers and filters used in the transposition of teachers' knowledge to teaching situations in classrooms (Carlson & Daehler, 2019; Gess-Newsome, 2015). In this way, the involvement with the elements that are part of the KTAtA model that we have investigated based on the manifestation of actions that contribute to science teaching involving argumentation is subject to beliefs held by the teacher in relation to the roles of argumentation in teaching. The teachers' beliefs seem to have a more significant influence upon the manifestations of actions of *structure* than the conceptual elements involved in the process of argumentation. In this study, evidence of the influence of the teacher's beliefs on her actions lies in the fact that she has frequently and consistently shown actions for the topics *process* and *function* in situations whose teaching purpose was that of argumentation.

With regard to the topic *function*, we highlight that the students have been involved in thoughts about the roles of argumentation (that is, they have been asked to think about the process of justifying or evaluating claims of knowledge based on available evidence or persuade an audience about the validity of a given viewpoint) when they discuss the arguments they created and expressed during the debate. The expressions of such actions suggest that Emma had some mastery of knowledge for teachers' actions through argumentation. Even though the actions shown could contribute so that the students could take on argumentation as an object of study and may develop metacognitive knowledge, the fact that this happened in only one of the four didactic sequences as analyzed may not have been enough for the students to develop such knowledge or argumentative skills.

CONCLUSIONS AND IMPLICATIONS

The instrumental case study produced from different particular types of didactic sequences led by an experienced teacher showed the possibility of integration between the constituent elements of PCK and the KTAtA model. In this integration process, we see that the goals established in the didactic sequences have had an influence upon the actions that contribute to science teaching involving argumentation as shown by the teacher. It therefore seems that, in didactic sequences involving argumentation with a focus on construction and evaluation of claims and scientific explanations, the teachers' actions are more often linked to the support and process topics. In these cases, the teaching strategies and materials are selected by the teachers seeking to make a certain item of content easier to be learnt by students (Shulman, 1987) and argumentation is used as a teaching strategy that contributes so that the students understand how claims and scientific explanations are generated, and why we should believe them (Osborne & Dillon, 2010). In this way, the constituent elements of KTAtA model are part of the teachers' PCK as orientation toward science teaching or as amplifiers and filters – which in turn contributes towards the implicit teaching of argumentation.

The teachers' PCK can also be linked to the teacher's understanding of the reasons to explicitly get argumentation involved within science teaching and the moments which are most likely for this to happen, considering a given context of teaching. In didactic sequences involving the explicit teaching of argumentation, the strategies and the materials used in teachers' planning seek to contribute to students' explicit thinking of the issue of argumentation. In this way, the knowledge that may support their actions through argumentation is essential so that they know how to create and conduct such didactic sequences, as they have goals that are different from those related to the teaching of scientific curriculum content. Thus, knowledge for teachers' actions through argumentation can be considered as an element of knowledge within the teachers' PCK, that shall be influenced by their personal PCK and shown in their enacted PCK.

Based on this conclusion, we draw attention to the importance of investigating teachers' knowledge based on the professional practice of teachers; and that the development of investigations over long periods and starting out from different didactic sequences can illuminate discussions on how teachers integrate the knowledge for teachers' actions through argumentation into their own PCK – which could show evidence of how argumentation can be part of the culture of a certain classroom. In this way, we stress that one implication of this work is related to the defense of a hybrid teaching of argumentation, involving moments of implicit and explicit teaching. Our assertive is supported by the facts that, in regular classrooms, teachers and students deal with different teaching purposes, and the explicit teaching of argumentation does not occur at all moments. In this regard, the constant involvement of students in argumentative process, albeit in an implicit form, seems to be just as important as offering opportunities for them to get involved in explicit processes of argumentation, as implicit teaching situations may contribute to the development of their argumentative skills through participation in argumentative situations while they learn scientific content (Schwarz, 2009).

In this study, we look into one single case study of the practice of an experienced teacher. Recognizing possible limitations in this procedure, we assert the need for other studies to analyze the practice of teachers with different profiles, as this can contribute to expand the understanding of how the knowledge for teachers' actions through argumentation is part of the teachers' PCK. One aspect that warrants investigation would be how collective PCK has an influence on the personal PCK and enacted PCK of a teacher inserted within a specific teaching context. For this, the practices of different teachers participating in a qualification program could be investigated in terms of how they create and lead didactic sequences involving argumentation within their classrooms.

In addition, recognizing that knowledge of the students and their characteristics is an important element of a teacher's PCK, we mention the importance of new studies investigating aspects of the relationship between teacher and student, which was not considered in the current study. For example, one important aspect to be analyzed would be how actions that contribute to science teaching involving argumentation as shown by a teacher may support his or her students' development, or enhancement, of their argumentative capacities. A study with this aim could contribute not only to the understanding of teaching involving argumentation in the classroom and its contributions to students qualifications, but also be grounds for new teachers educational processes.'

In this paper, we propose 27 types of actions that contribute to science teaching involving argumentation that could influence the involvement of students both in the argumentative process and in reflections about the structure and functions of argumentation. In this regard, some of its implications are linked to the possibilities of using the set of teacher actions for teaching involving argumentation in two different contexts.

As an analytical tool, the system of categories can be used in studies seeking to investigate the role of teachers within the science teaching involving argumentation in particular types of regular teaching situations. The actions are divided into four topics (*support*, *process*, *structure* and *function*) and, based on these, the researcher may discuss issues concerning the aims of the teacher in terms of argumentative practice and results he or she expects the students to achieve (as shown in this paper, by way of example).

In this regard, we stress that connecting teacher actions to the aims of the teaching process and then analyzing these from the viewpoint of teachers knowledge seems to be more interesting than the approach based on the categories of argumentation process, as used by Simon et al. (2006) and Yilmaz et al (2017). Using the actions, we have managed to identify the integration and articulation between different types of teacher knowledge that are used in a teaching situation. In addition, on thinking of the actions that contribute to science teaching involving argumentation from the perspective of the KTAtA model, we can relate them to teachers' knowledge of the conceptual and pedagogical dimensions of argumentation. Thus, it is possible to analyze teachers' actions towards the teaching of scientific curricular contents by using argumentation, such as, for example, the dimension of ' to request the presentation of a justification or explanation', as well as actions related to the teaching of argumentative practice, such as, for example, 'to define and/or exemplify the concept of evidence'.

From an analytical standpoint, in our study, we highlight that these actions can be shown in different ways by a teacher (as shown in the discussion of the action 'to encourage the student to evaluate an argument or a claim expressed by the very student or by a colleague') without this changing the nature of the action, which in turn facilitates the identification of the aims linked to it. This helps to soothe one of the main difficulties as mentioned by Yilmaz *et al.* (2017) with regard to the classification of an action as a meta-level one, depending on how it shows itself.

On the other hand, in agreement with Yilmaz *et al* (2017), we acknowledge the fact that the set of actions that contribute to science teaching involving argumentation can also enlighten discussions within the context of teacher education. Considering the links established between such actions and PCK in this study, the discussion of actions that contribute to science teaching involving argumentation may give pre-service teachers an opportunity to know, analyze, and reflect upon actions that could become part of the teaching practices that seek to create and involve students in argumentative teaching environments. This could contribute towards the enhancement of their collective and personal PCK (Carlson & Daehler, 2019). In addition, pre-service teachers may also experience situations (whether real or simulated) in which they act in the role of teachers teaching science involving argumentation. Based on this, they may take actions that contribute to science teaching involving argumentation and thus reflect about the role of the teacher within this process – which could also contribute to the development of their enacted PCK (Carlson & Daehler, 2019).

On the other hand, in the context of in-service teacher education, discussions about actions that contribute to science teaching involving argumentation may help so that teachers may establish a connection between their teaching practice and the teaching perspective involving argumentation, thereby nurturing the development of their enacted PCK (Carlson & Daehler, 2019). This may help teachers to perceive similarities and differences between their teaching practice and the perspective of teaching through argumentation. Therefore, the discussion of the actions that contribute to science teaching involving argumentation may help in-service teachers feel that their teaching practice is valued, and help them to perceive the links between argumentative practice and the teaching of scientific curricular content, thereby demystifying the idea that argumentation is another type of content to be included in the curriculum.

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