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Teachers' knowledge in argumentation: contributions from an explicit teaching in an initial teacher education programme

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ABSTRACT

Many researchers have highlighted the important role of teachers in creating and managing argumentative, as well as the need for teachers, during their training, to have opportunities to develop knowledge about arguments, enabling them to work from the perspective of argumentation. This study investigates to what extent a context of explicit teaching of argumentation contributed to developing this knowledge. The data sources include video records of explicit teaching of argumentation, collection of materials produced and used by pre-service teachers, and field notes. Analysis of the data indicates that the explicit teaching of argumentation influenced the conceptual learning of pre-service teachers concerning the elements interwoven into argumentative practice, especially evidence and justifications, and the development of pedagogical aspects in the context of argument. Although the pre-service teachers had expressed some teaching knowledge of argumentation in classroom discussion situations, the use of this approach in teaching situations still appears to be challenging for these teachers. The findings of this study highlight contributions to the area of teacher education in argumentation in terms of knowledge that is essential to plan and conduct argumentation-based teaching, and also to the structure of the initial teacher training programmes directed at teaching in argumentation.

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Introduction

Argumentation and science education

There has been an increasing number of discussions in the area of science education about the potential to teach science in a more authentic manner (Cavagnetto, 2010; Duschl & Osborne, 2002; McNeill & Pimentel, 2010; Sampson, Enderle, Grooms, & Witte, 2013). From this perspective, science education attempts to offer students the opportunity to engage in scientific practices so that they can understand science the way it is (Gilbert, 2004). In this context, argumentation can be used as a favourable approach because it is a practice inherent to science as a result of: (i) the need to justify and judge the appropriateness of models and theories according to the knowledge and evidence available; and

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(ii) the social nature of science, in which the constructs generated by scientists are open to discussion and rebuttals by the scientific community (Giere, 2001).

In terms of the use of argumentation in science education, many researchers have noted positive results in relation to the development of conceptual learning, and skills related to argumentation (Jiménez-Aleixandre & Pereiro Muñoz, 2002; McNeill & Pimentel, 2010; Mendonça & Justi, 2013; Sampson et al., 2013; Walker & Sampson, 2013). For example, in their investigation of the relationship between written arguments and students' conceptual learning during instruction based on argumentation, Sampson et al. (2013) realised that, in general, the students improved their understanding of the content, their knowledge about the scientific explanations, and their ability to use scientific explanations in interpreting natural phenomena.

In addition, the argumentative approach can contribute to develop citizenship, since it may contribute to decision-making and to developing a comprehensive view of science[1] (Jiménez-Aleixandre, 2010; Jiménez-Aleixandre & Erduran, 2008). However, argumentation-based science teaching not only demands a resignification of the educational purposes, but also requires that teachers assume their roles as agents responsible for developing argumentative practice in the classroom, and recognise that their role is to encourage students to work with evidence and justifications in constructing arguments (Bay, Reys, & Reys, 1999 apud Simon, Erduran, & Osborne, 2006).

The literature indicates some evidence of the importance of the teacher in fostering students' engagement in argumentation and in the following development of their knowledge related to this practice. For example, McNeill and Pimentel (2010) investigated the practice of three teachers working with instructional material that was explicitly directed towards argumentative practice and the relationship between this practice and the students' development of writing and social argumentation. The material used in this study involved a controversy on climate change, and fostered the creation of a context for scientific argumentation. The teachers received instruction on argumentation, but not on how to work with the material in the classroom. As a result of the study, the authors found that all students had a significant learning experience in terms of understanding the structural aspects of an argument. However, in terms of social argumentation, only the students in one group presented arguments that were connected to their classmates' arguments. The teacher of this group was the only one who (i) encouraged the students to debate the ideas presented by their classmates and to explain their agreement or refutation of these ideas; and (ii) used open questions to encourage the debate with and among students. In the other groups, this did not occur. With this result in mind, McNeill and Pimentel (2010) emphasised the use of open questions by the teacher as a method to improve classroom argumentation in terms of providing evidence for claims as well as to improve interaction among the students.

Evagorou and Dillon (2011) discussed the effect of two teachers' practices in argumentation among their students. The teachers worked at two different schools in a London suburb, with 12–13-year-old students. Using the Argue-WISE learning material,[2] they discussed why the population of red squirrels in the region had fallen. The teachers involved had the opportunity to discuss the material with the researchers, but did not receive any instruction on how to work with argumentation with their students. The analysis of the classes showed that the teachers used different approaches for working with the material. One teacher used a dialogic approach, discussing examples and validity of evidence with

the students and allowing them time to discuss among themselves. On the other hand, the second teacher did not give the students opportunities for discussion. The results of this study show that the first teacher's students were more successful in constructing arguments and providing alternative solutions to the problem than the second teacher's ones.

Studies like these show that the use of materials favouring argumentation is important, but that the teacher practice with these materials is crucial to attaining their purposes. Furthermore, these studies provide clues about how important it is for the teacher to possess and develop specific skills related to working with argumentation in the classroom. In this sense, Zohar (2008) argues that, in order to meet the demands of teaching through argumentation, a teacher must have first-hand experience with argumentative practices, either in pre-service or in-service training programmes, which foster the development of knowledge and skills to assist in the future implementation of argumentation in science classes. Nevertheless, there are still very few studies in this field that investigate the impact of teachers' professional development focusing on argumentation related to pedagogical knowledge (PK), especially in the area of pre-service teacher training programmes. In the following section, we discuss three studies that investigated the contributions of teachers' professional development focusing on argumentation, two looking at in-service programmes and one at pre-service training programmes.

Literature review

Teaching of argumentation in teachers pre-service and in-service education programmes

Baker (2009) discusses the existence of four types of argumentative situations in classes, depending on whether (i) there is one or more subjects discussing (ii) one or more distinct points of view. Considering that teachers need to develop their knowledge related to argumentation so that they can create argumentative situations in their classroom, some researchers have supported explicit teaching of argumentation in pre-service and in-service science teacher training programmes (McNeill & Knight, 2013; Simon et al., 2006; Zembal-Saul, 2009). This is because, from this perspective (which in the literature is known as explicit teaching), the aspects related to argumentation are highlighted by the teacher educator, the pre-service teachers are immersed in environments that foster first-hand experience with argumentative practice, and they are guided to reflect on this practice, which may encourage awareness about using argumentation in the context of teaching.

In the context of in-service teacher development, Simon et al. (2006) investigated skills concerning the teaching of argumentation of 12 teachers who participated in a professional development programme focusing on argumentation in order to understand how they could improve their practices related to the use of this approach. During the programme, the teachers had the opportunity to discuss argumentation-based activities in scientific and socio-scientific contexts (i.e. those that involve dilemmas and controversies that permeate the areas of science and everyday life (Jiménez-Aleixandre, 2010)). They were also introduced to a variety of teaching strategies and types of argumentation-based activities so that they could construct their own pedagogical practice. They also received instruction on how to structure activities focusing on argumentation, and how to conduct them, starting by proposing open questions.

Simon et al. (2006) discuss some issues related to teachers' practices regarding argumentation. First, the workshops allowed some teachers to change their practices, in the sense that they recognised that discussions of alternative theories provided opportunities for students to reflect, discuss, and debate the validity of evidence in support of the theoretical explanation. Second, teachers who demonstrated good practices for teaching argumentation at the beginning of the project (e.g. encouraging students to speak and listen) improved these practices by engaging in the project.

Still, in the context of teachers' in-service development, McNeill and Knight (2013) investigated the impact that teachers' professional development focusing on argumentation had on the teachers' pedagogical content knowledge (PCK) of argumentation. The teachers involved in this programme learned about the role of claims, evidence, and justifications; analysed videos of classroom situations involving argumentation and arguments written by students; and discussed students' difficulties related to argumentation. Additionally, the teachers had the opportunity to plan activities involving argumentation, exchange experiences related to implementing argumentation in their classrooms, and discuss a variety of strategies that could facilitate argumentative practices in the context of teaching and providing feedback to students on the quality of their arguments. The authors made some observations about their study. First, in analysing the students' written arguments, the teachers demonstrated their understanding of the meaning of evidence, and an improved understanding of claims and justifications. Second, in the classroom discussions, the teachers presented a limited understanding of argumentation in relation to both the structural components of arguments and the dialogical interactions. Third, although the teachers considered promoting argumentation in the classroom to be important, they found it difficult to formulate questions that fostered student argumentation, presenting restrictions on involvement of argumentation in the context of teaching (e.g. time and student engagement).

In contrast with the previous programmes, the work of Zembal-Saul (2009) was dedicated to initial training programmes for primary school science teachers. She discusses the results of studies investigating the development of future teachers' understanding about teaching science as argument, and their practices for teaching from this perspective. The participants in those teacher training programmes had the opportunity to develop their knowledge related to argumentation by: gaining first-hand experience of teaching science content as a scientific practice; observing discourse associated with teaching science as argument; watching videos of episodes in a classroom that depicted particular aspects of teaching from such an approach; and implementing activities that were planned using the teaching science as argument framework.[3]

Zembal-Saul (2009) also presents the results of a study that she conducted two years before, in which a group of teachers undergoing pre-service training, participated in the programme described above. The results indicated that teachers in pre-service training began to: perceive investigation in teaching as something important; emphasise the need for students to collect and analyse data and to build explanations based on evidence; prioritise discussions in the classroom; recognise the role of the teacher as a facilitator of student thinking and understanding; connect programme strategies with appropriate implications in the classroom.

In sum, all the studies mentioned above (McNeill & Knight, 2013; Simon et al., 2006; Zembal-Saul, 2009) indicate contributions made to teacher education by explicit teaching

of argumentation, since they show that this type of teaching fosters teacher reflection and understanding of *how* to teach science through argumentation. However, researchers who conducted investigations in the context of in-service teacher education (McNeill & Knight, 2013; Simon et al., 2006) indicate that teachers show resistance to argumentation-based teaching due to both the time required to apply it in regular classes, and the difficulties in changing their teaching practice. On the other hand, in the context of initial training, the pre-service teachers are building their identities as teachers, as well as their beliefs about the school culture, and have the opportunity to have access to the most recent discussions on the educational objectives and teaching strategies. Therefore, these individuals tend to have less resistance against the new perspectives of teaching than teachers who have been working for many years and/or have not been participating in training programmes.

Considering (i) the low number of studies, particularly in the context of initial teacher preparation programmes; (ii) the explicit contributions to initial teacher preparation programmes on argumentation which were shown in the few existing studies; and (iii) the fact that the teachers, in the context of their initial preparation, tended to exhibit less resistance to new educational perspectives; in this study, we set out to investigate and discuss the contributions of explicit teaching of argumentation in the context of an undergraduate teacher preparation programme. Specifically, we aimed at contributing to the literature in the area by investigating the following research question: to what extent, can a context of explicit teaching of argumentation contribute to the development of the knowledge necessary for pre-service teachers to teach science from an argumentative approach?

In our discussion of this research question, we highlight positive aspects and discuss the limitations of explicit teaching of argumentation in the context of an undergraduate teacher preparation programme, and we also provide evidence in favour of teaching argumentation in such programmes. From this point, we establish a dialogue between the knowledge produced in this study and what is found in literature, especially with regard to the knowledge that future teachers need in order to use argumentation in science classrooms in a manner that contributes to student education in science and citizenship.

Identifying and describing teachers' knowledge

Taking into account that our research question requests the analysis of the contributions of a given explicit teaching of argumentation in the development of pre-service teachers' knowledge on argumentation, it becomes necessary to identify which knowledge on argumentation the pre-service teachers were expected to learn.

As argumentation can be viewed from three perspectives – rhetoric, dialectic, and logic (Wenzel, 1990) – we tried to understand the contributions of each of them to argumentation-based teaching. The logic perspective emphasises the product of argumentation: the argument itself. For the logic, a good argument is constituted by claims supported by relevant and sufficient evidence and justifications. From the rhetoric perspective, the emphasis is on the process of producing an argument, that is, the argumentation, the production of an oral or written discourse that actually helps the members of a social group to solve a problem and make decisions from discussing distinct points of view aiming at persuading an audience of the validity of one of them. Finally, the dialectic perspective emphasises the procedure involved in the production of an argument, that is, it requires the existence of a

social contradiction. Thus, the plausibility of the argument will be established by the subjects involved in the argumentative process by following the structure of the argument, according to the logical perspective, or considering the validity in the context of enunciation (e.g. an argument can be appropriate in the social context but cannot be in a scientific context).

Therefore, to consider argumentative-based teaching from only one perspective limits it. For instance, as the logic approach is associated with the product, the arguments, the argumentative-based science education from such a perspective would focus only on the scientific arguments. Thus, the teacher's role would be to provide evidence and justifications for the scientific knowledge, which would mean an emphasis on the authoritative discourse.[4] On the other hand, to teach from the rhetoric perspective may imply in the teacher mainly trying to convince students of the validity of the scientific context. However, Driver, Newton, and Osborne (2000) highlight that such a teacher's attitude prevents students from learning to search for evidence and justifications for the scientific ideas. Additionally, according to them, science lessons have to support students' development of scientific skills. So, teachers have to give students opportunities to reason, to articulate evidence and justifications to support a claim, to try to convince their peers, to express doubts, to question, to express their alternative views. Finally, the focus of science teaching only on the dialectic may result in involving students in dialogic discourses,[5] making it difficult for the teacher to discuss knowledge that was produced, validated, and legitimated by a scientific community that view and explain the natural world from perspectives completely distinct from those of the students. In our view, such considerations show that all three perspectives may contribute to argumentation-based science teaching, thus helping to show the complexity of the process.

Taking into account the logic perspective, teachers should have knowledge about the basic structure of an argument, that is, to know that an argument is constituted by a *claim* supported by *evidence* (data that can support conclusions) (Jiménez-Aleixandre, 2010), and *justifications* (elements that connect evidence to claims) (Toulmin, 1958). This would allow them to discuss the evidence and justifications to a given scientific knowledge, as well as their meaning and importance.

By associating the rhetoric and the dialectic with the logic, it is important that teachers understand that knowledge being produced from the articulation between evidence and justifications implies that: (i) it can be refuted when new evidence or novel interpretation to old evidence is produced; (ii) distinct people can interpret evidence in different ways, thus generating alternative explanations to the same phenomenon; (iii) the analysis of the evidence or the theoretical models used to interpret the evidence can present limitations.

From the dialectic perspective, it is important that teachers understand that the evaluation and validation of evidence depend on the context in which the argument is produced. For instance, in a social context, personal experiences can be considered sufficient evidence to support a point of view. On the other hand, in the scientific context, this kind of data cannot be taken as evidence.

Moreover, with regard to argumentative skills, teachers have to know that: *to refute* is to generate an argument that invalidates the point of view of the other party participating in the discussion, *to generate alternative theories* means producing different interpretations

for the same evidence, and *to counter-argue* is to express an aspect of a personal argument which is faulty or can be proven false based on evidence (Kuhn, 1991).

In addition to this knowledge, we consider it important that teachers understand the motives or intentions that mobilise an argumentative situation, that is, argumentation within the dialogic sphere. Argumentation is associated with situations in which an audience is persuaded (Jiménez-Aleixandre & Erduran, 2008) or situations in which the goal is to establish consensus among an audience about the strength of a claim (Driver et al., 2000). Thus, there are relationships between these intentions of the argumentative practice, the basic elements of an argument (evidence, justification, and claim), and the argumentative skills (arguing, refuting, generating an alternative theory, and counter-arguing). For example, if someone's intention is to persuade an audience, he or she builds arguments using evidence that can support his or her personal theories, or reinterprets current evidence in order to invalidate the opposite point of view, that is, the person uses the elements of an argument to support a rebuttal. Therefore, an understanding of argumentative situations can contribute to the teacher trying to mobilise students' structural knowledge and their argumentative skills during discursive situations, whether these are directed at persuasion or establishing consensus, or in the scientific or socio-scientific context.

Although we consider the previously highlighted knowledge as essential for teachers to use argumentation in regular teaching contexts, we recognise that this knowledge alone is not enough for the teachers to know *how to create an argumentative environment in the classroom* and *how to conduct argumentative situations*. Such aspects are more tied to knowledge about the nature of the argumentative practice than to aspects related to how to encourage argumentative situations in the classroom, engage students in argumentative situations, and conduct these situations. In other words, just as content knowledge (CK) on any topic is not sufficient for a teacher to teach it (Berry, Loughran, & van Driel, 2008; Mavhunga, 2014; Shulman, 1986, 1987), knowledge about the practice of argumentation is not sufficient for the teacher to know *how to translate this knowledge into teaching actions*. Therefore, teachers need other knowledge in order to teach science through argumentation. This hypothesis is corroborated by studies investigating the relationship between the teacher's practice and the development of argumentation in classrooms (Evagorou & Dillon, 2011; McNeill & Pimentel, 2010) and by the work done by McNeill and Knight (2013) with teachers who experienced explicit teaching about argumentation. For example, McNeill and Knight (2013) concluded that teachers developed understanding about evidence and improved their understanding of claims and justifications, but had difficulties designing their own teaching activities involving argumentation and showed limitations in knowledge related to how to conduct argumentation-based teaching in their classrooms. According to the authors, this can be an indication that the teachers' training programme that the participants experienced did not help them to develop the knowledge needed to conduct argumentation-based teaching.

Therefore, in order to identify the elements of this other knowledge, we conducted a detailed analysis of the training programmes that were developed from the explicit perspective described earlier (McNeill & Knight, 2013; Simon et al., 2006; Zembal-Saul, 2009).

Based on this analysis, we identified that the authors used different methods to address argumentation with the participants. However, all teacher development programmes gave special attention to promoting opportunities for teachers to design activities based on

argumentation and to plan their own actions in favour of argumentative practice. This means that the coordinators of those programmes considered teacher knowledge related to designing and conducting argumentation-based teaching activities to be important.

Furthermore, in the literature in the area of argumentation, we looked for clues related to teachers' practice in creating and guiding argumentative environments. For example, in studies investigating the contributions of argumentative practice in the science education context (Evagorou & Dillon, 2011; McNeill & Pimentel, 2010), we found that successful actions on the part of the teachers promoted the development of student argumentation.

By putting all the previous ideas together, we propose that, in order to teach through argumentation, teachers' knowledge has to be closely related to knowledge of:

- *teaching strategies to promote argumentation*. This knowledge refers to the variety of strategies that may be used by the teacher in order to engage students in argumentative situations. For example, the teacher can create an argumentative environment in the classroom based on: experimentation, investigative activities, posing controversial questions, setting up a mock trial, etc.;
- *instructional materials that are consistent with the argumentation-based teaching approach*. It is essential that teachers have knowledge about the characteristics of the materials which foster the development of argumentation (such as, e.g. the fact that they must involve problems that allow multiple responses), so that they can judge their appropriateness considering their current teaching purposes and, in turn, create their own materials. It is also important that teachers get to know various instructional materials so that they can identify what material is best for argumentation-based teaching of a particular topic in a specific educational context, or for teaching the argumentative practice itself;
- *actions that encourage argumentation-based teaching*. It is important that teachers understand what actions can and should be undertaken so that they can engage students in argumentative practices, design argumentative environments based on instructional materials, and so on. For example, while teaching a topic involving experimentation, the teacher may use open questions to ask for students' justifications for their empirical observations and conclusions; or, when students express diverging ideas, the teacher can stimulate them to discuss the validity of their ideas, their justifications, and the evidence presented.

Besides such knowledge indicated in the literature, we considered that another essential element for teachers is the mastery of skills to guide argumentative situations in the classroom, namely,

- to transpose structural knowledge of argumentation in order to mobilise argumentative skills for dialogical situations; and
- to know how to use teaching strategies, instructional materials and activities that favour argumentation-based teaching in regular teaching contexts in such a way that they effectively foster the occurrence of argumentative situations among students and between the students and the teacher, as well as the development of argumentative skills among students.

In this study, *which was carried out in the context of an initial teacher education programme*, we called the whole set of such teachers' knowledge 'knowledge for teacher's action through argumentation' (Figure 1). This is because we recognise that this knowledge can still be changed in a real teaching situation, since in these situations it can be influenced by other interwoven knowledge possessed by the teacher (e.g. knowledge of the school context and the teacher's teaching experience). Since these are not always accessible to pre-service teachers, we consider that the knowledge developed in the initial preparation programme can be understood as knowledge of a theoretical–practical nature[6] that can sustain the future practice of teachers in argumentation-based teaching contexts.

Although we have highlighted the theoretical dimension of knowledge of argumentation developed during the initial teacher preparation programme, we do not think of this knowledge as CK. This is because the teacher's CK involves understanding the structure of the content, which according to Schwab (1978 apud Shulman, 1986) would include substantive and syntactic structures. The substantive structure is related to understanding the variety of ways to organise a subject by incorporating the content, while the syntactic structure refers to a set of rules that determines what is legitimate in a subject domain or the validity of competing ideas. Therefore, CK does not exhibit any element related to didactic aspects, that is, to *how to teach* the content in the classroom. However, keeping in mind that *knowledge for teacher's actions* involves knowledge linked to the nature of argumentation, as well as to how to create and mediate argumentative environments in the teaching context (that is to say, the use of argumentation in the classroom), we emphasise that it is not adequate to consider knowledge of argumentation developed during initial teacher training to be CK.

Considering the theoretical nature of the knowledge that is involved in initial teacher preparation programmes, we also chose not to use the nomenclature PCK. In the literature (e.g. Berry et al., 2008; Mavhunga, 2014; van Driel, de Jong, & Verloop, 2002), there is a consensus that PCK derives from teaching practice, which requires development over the years through a reflective process of 'trial and error' (as discussed, for instance, in Loughran, Berry, & Mulhall, 2006). This close relationship between PCK and teaching

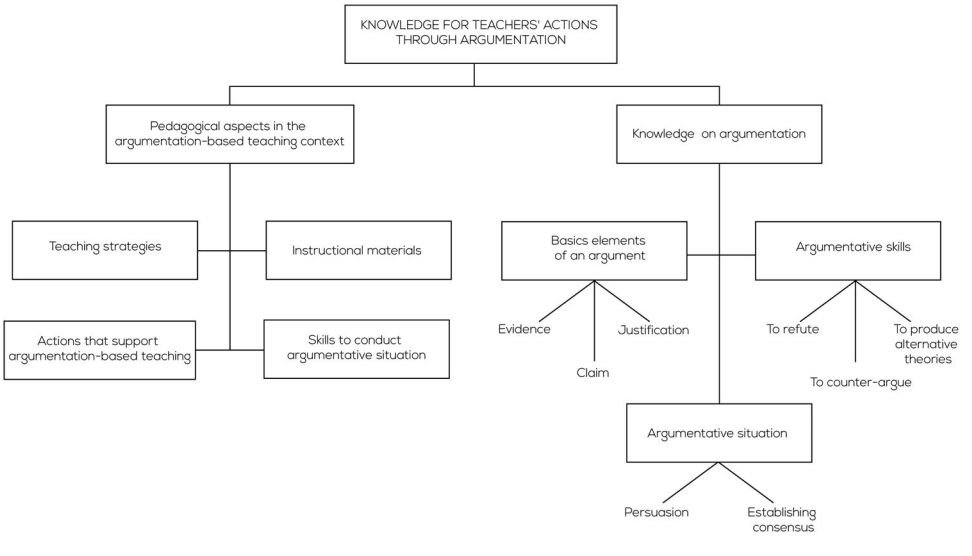

Figure 1. Components and structure of the knowledge for teachers' action.

practice is reflected in the improbability that pre-service or even novice teachers will exhibit high levels of PCK or high-quality PCK (Berry et al., 2008; Bertram & Loughran, 2014; Mavhunga, 2014). The use of this nomenclature is also impossible due to the fact that PCK is closely related to the *content*, that is, PCK means the teacher's knowledge of how to make *a given content* understandable to the learners (Magnusson, Krajcik, & Borko, 1999; Shulman, 1986, 1987; van Driel & Berry, 2012; van Driel, de Vos, Verloop, & Dekkers, 1998). This is indicated in the very name of the construct, as PCK may be viewed as an amalgam of CK and the teacher's general PK (Shulman, 1986). Therefore, considering that (i) in the context of initial teacher preparation programmes, teachers have few opportunities to teach using argumentation and to reflect on this process (mainly due to the length of the programmes); and (ii) argumentation is not a content area that is added to the syllabus, but instead, a basis of an approach that can be incorporated into the process of teaching scientific content and developing competencies, we acknowledge that it is not appropriate to name pre-service teachers' knowledge as PCK.

Zohar and Schwartzer (2005), in their discussion of the teachers' knowledge related to the context of teaching higher order thinking skills, stressed the fact that it was not enough to fit this knowledge into teachers' general PK. According to them, this construct does not provide the specific expertise required for teachers to successfully meet the aim of developing the students' reasoning. This is because the teachers' knowledge of higher order thinking skills involves metacognitive knowledge – that is, knowledge about the knowledge of the higher order thinking skills – and knowledge about how to engage students in a process of reflection on the meaning of higher order thinking skills. For this reason, the authors have chosen to name this type of teachers' knowledge as *PK in the context of higher order thinking skills*.

Similarly, we recognise that teachers' knowledge of argumentation extrapolates the domain of the teachers' PK, because for teachers to use and design strategies, materials, and actions that are suited to the aim of developing students' argumentative skills, they need specific knowledge about the nature of argumentation (e.g. an understanding of evidence). In this sense, we recognise the possibility of considering this knowledge as *PK in the context of argumentation*. Nevertheless, considering the proposal of Zohar and Schwartzer (2005), PK in the context of argumentation should involve metacognitive knowledge of argumentation, which could mean the teacher's knowledge about the involvement of students in the processes of reflecting on the validity of the arguments produced and of selecting data in constructing evidence, etc. In this sense, knowledge about how to engage students in constructing metacognitive knowledge of argumentation will depend on the teacher's practical experiences in the context of argumentation-based teaching. This is because the teacher needs opportunities to practise and reflect on the process of relating actions, strategies, skills, and knowledge on the nature of argumentation in developing the students' metacognitive knowledge of argumentation.

In this section, we have discussed about the impossibility of recognising pre-service teachers' knowledge on argumentation as PCK, CK, or even PK in the context of argumentation. From such a discussion, we emphasise our option for proposing a set of knowledge that may characterise, in a proper and comprehensive way, the teachers' knowledge specific for planning and conducting argumentation-based teaching situations. This set of knowledge – that we named *knowledge for teachers' action through argumentation* – has a theoretical nature, since it was built from our understanding of (i) distinct theories on

argumentation, (ii) previous teachers' education programmes focused on argumentation, and (iii) the role of argumentation in science teaching. Therefore, it comprises a series of components (as summarised in Figure 1). Assuming the relevance and comprehensiveness of this set of knowledge, in this paper, we use it to investigate the contributions of a given explicit teaching of argumentation to the development of pre-service teachers' knowledge needed to plan and conduct argumentation-based science teaching situations.

Methodology

Research context

The teacher preparation programme under which the explicit teaching of argumentation investigated in this study took place was a course taught to the pre-service teachers in their last term of an undergraduate programme in chemistry teaching at a public university in southwest Brazil.[7] This course discussed the following topics: argumentation, investigative activities, and experimentation in chemistry teaching. The teaching of the first topic followed a methodology based on providing students with experiences in argumentation, followed by discussions about aspects of argumentation that were deployed on these experiences. To do so, the teacher educator involved the students in practical activities that covered elements or aspects related to argumentation (e.g. the meaning of evidence and its role in building arguments, central characteristics of instructional materials that can encourage argumentation in class, etc.). Afterwards, she asked them to read texts related to the aspects involved in the previous activities and encouraged classroom discussions about the texts, about the experiences with the activity, and about her own actions as facilitator in discussing the activities. In addition, the teaching of this topic involved pre-service teachers planning and presenting a 50-minute demonstration lesson explicitly involving argumentation.

For discussions about investigative activities and experimentation in chemistry teaching, the teacher educator provided the pre-service teachers with texts and activities on the topic, and promoted a classroom discussion about them. As the closing activity and final assessment for the course, the pre-service teachers prepared and gave a mock lesson involving the three topics discussed in the course. Table 1 provides more details about the lessons (each 100 minutes in length) that took place during this teachers' training programme.

It is important to highlight that argumentation permeated all the discussions that took place throughout the course. Moreover, we observed that in teaching argumentation, the teacher educator also taught how to use argumentation in chemistry classrooms in secondary education. We noted this direction in teaching when we perceived that, in addition to the discussions on intentionalities related to argumentation and to the elements that structure an argument and argumentative skills, the teacher educator also gave the pre-service teachers opportunities to create activities involving argumentation, to develop argumentation in the classroom from the simulated situations, and highlighted actions that encourage the creation of argumentative environments. So, the teacher educator gave the pre-service teachers an opportunity to develop knowledge about the structure of argumentation, PK related to argumentation-based teaching, including specific pedagogical practices, and understanding of the argumentation-based teaching approach. We therefore consider that the teaching of argumentation investigated in this study corresponds to a teaching of argumentation from an explicit perspective.

Table 1. Description of the lessons in the course, with special emphasis on those in which the explicit teaching of argumentation occurred.

Month	Lessons	Activities
May	1	Performance and discussion of the 'Halloween Crush' activity (Erduran & Pabuccu, 2012) (Activity 1), which presents the case of a group of young people in a chalet who were surprised by an accident involving an olive oilcan, followed by two questions ('Why did the lid burst?' and 'Why did the oilcan crush?') and a series of reasons that could be used to answer the questions. The pre-service teachers were to assess the reasons as 'more relevant' and 'less relevant' and justify each assessment they made.
	2	Discussion of the text 'Argumentar consiste en evaluar los enunciados en base a pruebas' ('To argue is to evaluate statements based on the evidence') (Jiménez-Aleixandre, 2010) (Text 1). The text approaches discussions about the meaning of argumentation and authoritative arguments, the possibility of multiple interpretations of evidence, and argumentation as a social process.
	3	Performance and discussion of the activity 'Why do we know what we know?'[a] (Jiménez-Aleixandre, Gallástegui Otero, Eirexas Santamaría, & Puig Mauriz, 2009) (Activity 2). In this activity, several claims related to chemical content are presented (e.g. salt water is a mixture), and evidence and justifications are to be provided for each.
	4	Discussion of the text 'La argumentación contribuye a competencias básicas y objetivos generales de la educación' ('Argumentation contributes to basic skills and general aims of education') (Jiménez-Aleixandre, 2010) (Text 2). This text discusses the contributions of argumentative practice to student learning 'about science' and 'in science', and to the development of critical reasoning.
June	5	Performance and discussion of the 'Copernicus' Skull' activity (Jiménez-Aleixandre, 2010) (Activity 3). The activity consists of a text in which data are presented and should be used to tell whether or not a skull that was found belonged to Copernicus.
	6	Discussion of the text 'Los criterios para evaluar pruebas incluyen especificidad, suficiencia, fiabilidad' ('The criteria for evaluating tests include specificity, validity, reliability') (Jiménez-Aleixandre, 2010) (Text 3). The main focus of this text is the discussion about interpreting evidence, which involves the criteria used to evaluate them. In this sense, the meaning of reliability, validity, and specificity of evidence is approached.
	7	Performance and discussion of the 'Snowmen' activity[b] (Osborne, Erduran, & Simon, 2004) (Activity 4). This activity presents a scientific problem for which the pre-service teachers had to choose the answer they considered correct out of two options. The problem also involved issues that encouraged the expression of argumentative skills: generation of arguments, alternative theories, counterarguments, and rebuttals.
	8	Discussion of the text 'La argumentación socio científica contribuye al pensamiento crítico' ('The socio-scientific argument contributes to critical thinking') (Jiménez-Aleixandre, 2010) (Text 4). This text addresses the meaning of socio-scientific issues and the contributions of activities involving them to the development of students' critical thinking, learning about science, and decision-making.
	9 and 10	In pairs, preparation of mock lessons that explicitly encourage argumentation, and discussion with the teacher educator about the intended lessons.
	11	Mock Lesson 1 by two pairs: Rachel and Lara, Laura and Gisele.
July	12	Mock Lesson 1 by the pair Maria and Isis.
	13–18	Discussion of investigative activities and experimentation in chemistry teaching.
August	19–24	In pairs, preparation of mock lessons that involve the aspects discussed in the course with relation to: investigative activities, experimentation and argumentation; and discussion with the teacher educator about the intended lessons.
	25	Mock Lesson 2 by Gisele.[c]
	26	Mock Lesson 2 by Lara and Laura.
	27	Mock Lesson 2 by Isis and Rachel.

[a]The material used by the teacher educator was an adaptation of this activity. Different from the original material, the material used in the course only presented claims related to chemistry.
[b]The material used in class by the teacher educator was an adaptation of this activity. Different from the original, the new material featured questions based on the argumentative skills discussed by Kuhn (1991).
[c]Maria did not participate in the final demonstration lessons, so Gisele gave the lesson alone.

Participants

The teacher educator holds a degree in chemistry as well as master's and doctorate degrees in science education, and her doctoral thesis research involved analysing arguments made by secondary school students. In our view, her knowledge in the area of science education, especially in relation to argumentation, was essential to encourage the discussions about

argumentation in chemistry teaching that took place in the course. Furthermore, the teacher educator's prior experience as a secondary chemistry teacher allowed discussions on the appropriateness of the pre-service teachers' proposals for regular chemistry teaching at the secondary level.

Six pre-service teachers, all female, participated in the course. In this study, they are identified by pseudonyms: Gisele, Isis, Lara, Laura, Maria, and Rachel. Since they were almost at the end of their teacher preparation programme, they had taken virtually all the chemistry courses, and had previously taken courses related to general pedagogical content and other specific subjects for teaching science. Therefore, they had sufficient knowledge to engage in discussions about the content involved in the explicit teaching of argumentation and to develop other related knowledge. Until the data collection was completed, the pre-service teachers had had no teaching experience; in other words, they had never taught in a regular classroom.

Data collection

All of the lessons that took place during the training programme were observed and video-recorded. The video was recorded by just one of the researchers, using a single camera. Consequently, in the classes that involved the pre-service teachers' participation in the activities and preparation of the mock lessons, in which the pre-service teachers worked in pairs, it was not possible to record all of the discussions. However, when the pre-service teachers requested the teacher educator's presence to discuss something, the researcher followed her with the camera to capture the discussion. Furthermore, since the data were collected during the course lessons, it was not possible to access the lessons' preparation stages that occurred outside the classroom.

During the explicit teaching of argumentation, the pre-service teachers prepared two mock lessons (i.e. those that they taught within the course itself, with their classmates and other Chemistry undergraduates as 'students'). One of these lessons explicitly involved argumentation (Lessons 11 and 12, Table 1), whilst the other involved all of the content discussed in the course (argumentation, investigative activities, and experimentation) (Lessons 25, 26, and 27, Table 1). We considered it important to collect these lessons' written preparation, because they could be a source of data about the pre-service teachers' knowledge on argumentation at that specific time.

The pre-service teachers' response to the activities, that is, their written arguments, were not collected as data in this study. This is because we focus our data collection on the aspects of oral argumentation, namely those originating from the discussions between the teacher educator and the pre-service teachers.

Data analysis

Data were analysed qualitatively, by following an inductive process. First, the videos were analysed aiming at identifying all parts of the class verbal and non-verbal interactions that may be relevant for the purpose of the study. From this analysis, all of the lessons were described in detail and the dialogues that took place during discussions of the activities about argumentation were transcribed. Once we had the transcription of the data, in chronological order, we constructed a case study that describes the processes of teaching

and learning related to argumentation experienced by our subjects. The purpose of constructing the case study was to present the activities and texts that were discussed during the teaching period, to highlight the actions and the statements of the teacher educator that may have contributed to learning on the part of the pre-service teachers, and to point out manifestations by the pre-service teachers related to difficulties in learning related to argumentation.

Considering the case study, we conducted a detailed analysis based on the theoretical construct knowledge for teachers' action through argumentation. As previously discussed, it is the set of knowledge necessary for pre-service teachers to teach science from an argumentative approach. Moreover, knowledge for teachers' action through argumentation is related to (i) the teachers' understanding of the nature of argumentative practice, which involves understanding the structure of an argument, argumentative skills, and mobilisation of this knowledge in dialogical situations; and (ii) knowledge about pedagogical aspects relating to argumentation-based teaching, which includes: teaching strategies, instructional materials, actions that support argumentation-based teaching, and skills to conduct argumentative teaching situations (Figure 1). So, we conducted a detailed analysis of the classes, considering the aspects that constitute the knowledge for teachers' action through argumentation as units of analysis. That meant to take into account seven categories: teaching strategies, instructional materials, actions that support argumentation-based teaching, skills to conduct argumentative situations, basics elements of an argument, argumentative skills, and argumentative situation. The categories that comprise knowledge on argumentation were analysed by taking into account each of their elements (represented on the right side of Figure 1). On the other hand, the categories that comprise the knowledge involved into the pedagogical dimension are related to teachers' beliefs concerning the argumentative approach. Thus, the components involved in the pedagogical dimension of teachers' knowledge are less distinct in practice than in theory, but it serves as useful heuristic for thinking about and studying teacher knowledge (Grossman, 1990), in our case, on argumentation.

In the stage of analysing the case study, both authors, working independently, identified the moments (i) when the teacher educator taught some aspect of the knowledge related to argumentation, and (ii) in which the pre-service teachers showed understanding or doubt related to learning these elements. Then, the two authors discussed and negotiated any inconsistencies in their individual analysis. Therefore, triangulation was promoted from multiple data sources and from the participation of two researchers who analysed the data.

From this analysis, we constructed Table 2, which shows some evidence of the processes of teaching and learning related to argumentation. Finally, we interpret Table 2 in the light of our research question in order to discuss it, that is, we discuss the changes in specific aspects of the pre-service teachers' knowledge assuming that learning is a dynamic process, and that the pre-service teachers' previous knowledge, the knowledge built during the instruction, and particularities of the instruction process influenced their learning in specific contexts of the instruction.

Results

Due to the large volume of data collected and the extent of the case study, in this paper, we present, in Table 2, a summary of all the classes that can be characterised as explicit

Table 2. Observations about the events in the class and participation by the pre-service teachers.

Lessons	Most relevant observations about the lessons	Observations about the participation of pre-service teachers
1	• From the discussion in Activity 1, the teacher educator stressed characteristics of the materials targeting explicit argumentation (e.g. requesting the analysis of evidence and presenting justifications for the statements) and drew attention to the essential characteristics of the instructional materials that can favour argumentation. • Returning to the discussion of the responses given by the pre-service teachers to Activity 1, the teacher educator discussed justifications and data analysis with them.	• Isis and Rachel expressed difficulties related to understanding the concept of justification. At these times, the other classmates used examples to explain the concept of justifications to the pair. • When requested to present essential characteristics of the materials, all the pre-service teachers highlighted that the problem has to: exhibit more than one variable, be open, and allow for multiple interpretations.
2	• The teacher educator discussed the aspects of argumentation addressed in Text 1 and stressed the importance of teachers using open questions to engage students in argumentation-based teaching.	• Based on the discussion of the text, Maria learned about the possibility of presenting evidence for scientific knowledge.
3	• From the discussion in Activity 2, the teacher educator reinforced the concepts of evidence and justifications and stressed the role of specific evidence. She also drew attention to a feature of materials that fosters argumentation: the possibility of non-consensual responses.	• Initially, all of the pre-service teachers expressed difficulties in presenting evidence for the chemistry-related claims. • Gisele demonstrated understanding of the role of justifications in the generation of arguments. • At the end, all of the pre-service teachers acknowledged the importance of posing questions so that argumentation may occur in teaching.
4	• Based on the discussion of Text 2, the teacher educator stressed the importance of argumentation in students' education. • Reminding them of Activity 1, the teacher educator stressed the importance of the questions she used to engage the pre-service teachers in argumentation again.	• All of the pre-service teachers recognised the characteristics and importance of the materials used to foster argumentation in the classroom.
5	• From the discussions in Activity 3, the teacher educator emphasised the main feature of this material: the use of text to present data that need to be interpreted.	• From the discussions about specific evidence, Maria reported that she struggled to mobilise this kind of evidence in Activity 2.
6	• The teacher educator discussed Text 3 and established relationships between the text and Activity 3, in which no data could be used as evidence specific to the case.	• Lara demonstrated understanding of specific evidence by connecting the concept with Activity 3.
7	• From the socialisation of the responses to Activity 4, the teacher educator discussed the meaning of argumentative skills presented in this activity.	• All of the pre-service teachers stated that they understood the discussion about argumentative skills involved in the activity.
8	• The teacher discussed the aspects that were stressed in Text 4 and emphasised the contributions of the use of socio-scientific questions to forming critical citizens and to the science learning.	• All of the pre-service teachers recognised the differences between the materials that involved scientific, socio-scientific, and social issues.

(*Continued*)

Table 2. Continued.

Lessons	Most relevant observations about the lessons	Observations about the participation of pre-service teachers
9 and 10	• During the planning of the mock lessons, the teacher educator suggested that in their proposal, the pair Rachel and Lara used the education strategy based on role-play.	
11	• Lara and Rachel produced a text that present data that could be used to support arguments for and against the use of plastic bags. They suggested that a mock trial involving the two positions be carried out to discuss the issue. • Gisele and Laura designed an activity that presented the case of a teenager who wanted to lose weight and, to do so, needed to choose one of three diets. During the course of the activity, information about the diets was presented to be used in the generation of arguments for or against their use. In addition, at the end of the activity, the students were asked to propose an alternative diet.	• Lara and Rachel wrote a text that presented little evidence. Furthermore, Lara expressed difficulties in differentiating evidence from justifications while generating an argument. • In their proposal, Laura and Gisele presented data that could be used as evidence during the analysis of the diets, and properly used the concept of justifications in the topics they proposed. In addition, the activity permitted multiple responses to the question. • The two pairs created activities involving socio-scientific issues.
12	• The activity designed by Isis and Maria comprised a comic book, which told the story of a young woman who straightened her hair, and a few days afterwards noticed that some strands of hair had broken off. The activity also presented data about formaldehyde (which is usually used in hair straightening) and the fact that the young woman had been in the sun and had also come into contact with seawater. The proposed questions favoured manifestation of argumentative skills.	• Isis demonstrated knowledge of the use of specific evidence when pointing out the importance of using the information about formaldehyde. • The pair used the concept of justification in the questions they proposed, and created an activity involving a socio-scientific issue.
13–18	• The teacher educator established relationships between investigative activities and argumentation, and promoted discussions about both the types of investigative activity and the possibility of using them to create an argumentative environment. • The teacher educator stressed the potential of using investigative experiments to further argumentation in the classroom.	
19–24	(Lessons dedicated to planning the activities)	
25	• Gisele proposed that the colligative property of ebullioscopy be discussed after an experimental activity. The activity involved preparing coffee, and, from this, the participants would produce models to explain what was happening during the process. Gisele proposed that argumentative skills were discussed from the production and discussion of the models. Through the discussions of the activity, the pre-service teacher introduced the concept of ebullioscopy.	• Gisele presented evidence related to the phenomenon investigated and used it to support the scientific claims. However, she did not discuss the evidence mobilised by the participants of the mock lesson. • Gisele appropriately used the concept of justification in the questions posed in the activity, and during the discussion, she presented justifications that supported the evidence. Furthermore, she asked the 'students' to present their justifications for the observations they made. • The instructional material allowed the demonstration of different responses and the collection of data that were to be used in constructing evidence to support the production of models to explain the phenomenon in question.

26	• Laura and Lara prepared an experimental activity in which a calorimeter was made and two foods were burnt: peanuts and Brazil nuts. Based on the results of this experiment, they discussed the meaning of the term calorie and the occurrence of experimental errors.	• During the discussion of the activity, the pair highlighted the data that could be used as evidence in the discussion about the discrepancy between the theoretical and the experimental results. • Lara and Laura properly used the concept of justification in the questions posed in the activity, and asked the participants in the demonstration lesson to show their justifications for the procedures they carried out. • • The instructional material that they created permitted the emergence of different responses and the collection of data to be analysed in constructing evidence to support the experimental conclusions.
27	• Isis and Rachel built an experimental activity involving the phenomenon of paper chromatography. The experiment consisted of conducting chromatography using three pigments: blue, green and purple ones. The pair used water as a solvent and the pigments were taken from M&M's® candy using a wet brush.	• During the activity, Isis and Rachel highlighted the data that could be used as evidence (e.g. the fact that dry M&M's® did not transfer their colour to the paper). However, the activity did not present data that could be used as evidence in the conclusion that the water was the medium that carried the pigment. • The pair properly used the concept of justification in the questions posed in the activity, and conducted questioning with the intention of engaging students in the argumentative practice.

teaching of argumentation (identified in Table 1) and of our main observations. Next, in order to illustrate the analysis that was performed, we select from the case study the results related to the development of one of the category basic elements of an argument: evidence. As discussed in the previous section, similar analyses were performed for all the other categories. However, due to space limitations, we show only few aspects concerning some of them in this paper.

Evidence

Discussions about evidence that took place in the explicit teaching of argumentation involved: its conceptualisation; its role in generating an argument; the meaning of specific, reliable, and valid evidence for a claim; the role of evidence in producing scientific knowledge; the difference between data and evidence; the need to interpret data in order to construct evidence; the 'weight' of a datum or set of data as evidence; the sufficiency of only one piece of evidence or many evidence to support a conclusion; and the possibility of multiple interpretations of the same datum or set of data.

The observations related to Lessons 2 and 3 (Table 2) indicate that the pre-service teachers had little previous knowledge about the use and meaning of evidence in constructing statements. This claim is based on the facts that: (i) when reading the first text proposed by the teacher educator, Maria reported that she did not know it was possible to work with evidence related to scientific knowledge; and (ii) in Activity 2, the pre-service teachers had difficulties presenting evidence for the chemistry-related claims. As shown in Tables 1 and 2, Lessons 11, 12, 25, 26, and 27 were intended for the pre-service teachers to present their mock lessons that explicitly involve argumentation. In Lessons 11 and 12, the pre-service teachers, with the exception of Lara and Rachel, demonstrated knowledge about the role and significance of evidence, because they inserted data into the activity in such a way that it could be used as evidence in building conclusions. By including little evidence in the text they wrote for the activity (as highlighted in Table 2), Lara and Rachel demonstrated their limited knowledge of evidence and its role in generating arguments at that time. This can also represent a limitation in knowledge of instructional materials suitable for teaching by argumentation.

Furthermore, in Lessons 25, 26, and 27 (Table 2), we observed that all the pre-service teachers thought of activities that allowed participants to analyse and collect evidence, which may be aligned to knowledge of teaching strategies. By thinking of the data that would be made available to the participants to construct evidence in the mock class, the pre-service teachers demonstrated knowledge of evidence. However, the proposal by Isis and Rachel (Lesson 27, Table 2) lacked data that would help class participants to conclude that water interacted more with the pigment, thus being able to 'carry' it. In other words, the activity did not have specific evidence that would support the students' conclusion about the relationship between such interactions and the water's carrying ability. In this case, the limitation shown by Isis and Rachel was more associated with the knowledge of evidence in relation to its role in constructing scientific knowledge than to the knowledge of teaching strategies. This may be because the experimental activity involved working with data, but they were not aware of the fact that no data available could be used as specific or sufficient evidence (e.g. the fact that the water, a polar

solvent, 'carries' more pigment than a nonpolar solvent) to support the scientific knowledge involved in the experiment (intermolecular interactions).

In particular, we noted that, during her mock lesson (Lesson 25, Table 2), Gisele did not discuss the evidence that the participants in the lesson expressed. She also used the available evidence to support authoritative discourse. Laura and Lara (Lesson 26, Table 2) stressed experimental aspects during their lesson so that the participants could be aware of the possible evidence for discrepancies between the experimental results and the theory. Isis and Rachel (Lesson 27, Table 2) sought to introduce evidence that could contribute to constructing knowledge about the interaction between water and pigment. However, they did not provide specific evidence to help the 'students' support the conclusion that the water interacted with the pigment and therefore carried it on the paper. It is worth noting that the difficulties that the pre-service teachers experienced in mobilising evidence in the simulated teaching situations can be associated with a limitation in their knowledge of skills to conduct argumentative teaching situations.

Overview of other categories of the knowledge for teachers' action through argumentation

The analysis of *justification*, another element of the category basic elements of an argument, showed that discussions related to this element mainly involved its concept. In general, most of the doubts were expressed by Isis and Rachel in the first lesson (Lesson 1, Table 2). However, in Lesson 7, when questioned by the teacher educator about which element helped to support an opinion, Gisele stated that it would be justification, showing that she understood the meaning of this element. Furthermore, Gisele expressed an understanding of the meaning of justification by introducing an appropriate justification for the assertion that salt water is a mixture (Lesson 3, Table 2). When preparing the mock lessons (Lessons 11, 12, 25, 26, and 27, Table 2), the pre-service teachers expressed knowledge about justifications by correctly using the command 'justify' in the questions that they proposed. However, in Lesson 11, Lara expressed confusion between 'evidence' and 'justification' by formulating a justification rather than a piece of evidence for the controversy related to the use of plastic or biodegradable bags. At that time, this indicated a poor understanding of the concepts of evidence and justification, because Lara did not recognise her response as a piece of evidence or as a justification. It was the teacher educator who reported that what she had said was a justification for the case.

With regard to the argumentative skills of *generating alternative theories and counter-argumentation*, our analysis indicates similar results. First, the pre-service teachers demonstrated conceptual knowledge of skills for proposing alternative theories and counter-argumentation by formulating questions on the materials produced for the mock lessons (Lessons 11, 12, 25, 26, and 27, Table 2) – which could scaffold the development of their knowledge of the instructional materials. Although the materials used in the first mock lesson could favour the development of skills by the pre-service teachers, we did not observe discussions among them about the importance of this skill in order to develop citizenship. This also demonstrates a limitation in their knowledge of skills to conduct argumentative situations.

As for the skill of *generating refutations*, we perceived that the pre-service teachers demonstrated conceptual knowledge concerning formulation of questions in the materials they prepared for the mock lessons (Lessons 11, 12, 25, 26, and 27) that encouraged the manifestation of refutation. Additionally, at times, the pre-service teachers were able to create rebuttals during the discussions with their mates. However, we noticed that there was a difference between the mobilisation of knowledge of refutation in the discussions among the pairs (which took place, e.g. in Lesson 17, Table 2) and the mobilisation of this knowledge in teaching situations (e.g. in Lesson 19, Table 2). Therefore, it seems that the mobilisation of knowledge about refutation in a teaching situation, even a simulated one, depends on the teacher's other knowledge, such as chemistry CK, skills to conduct argumentative situations, and so on.

In terms of the pedagogical dimension of the knowledge for teachers' action through argumentation, the analysis of the category *teaching strategies that encourage teaching through argumentation* indicates relevant contributions related to the use of socio-scientific issues, because these had a strong impact on the development of knowledge among the pre-service teachers. This is because all of the participants chose to work with socio-scientific issues when planning their first mock lesson (Lessons 11 and 12), which required them to explicitly involve argumentation without necessarily having to teach chemistry-related content using argumentation.

With regard to the category *instructional materials that encourage teaching through argumentation*, the actions of the teacher educator with respect to this knowledge aimed at highlighting both the characteristics of the materials that can contribute to argumentation in the classroom (e.g. leaving the conclusion open, the possibility of non-consensual responses, etc.) and some types of materials that are suitable for this practice (such as the use of text containing data, investigative activities, and experiments). With regard to the preparation of the instructional materials, the proposals they created for their first mock lessons (Lessons 11 and 12, Table 2) were based on activities presented in class by the teacher educator, except those created by Gisele and Laura. For example, Isis and Maria presented questions that favoured the manifestation of argumentative skills, but the writing in this proposed activity was very similar to the questions in Activity 4. In contrast to the instructional materials produced and used in the first mock lesson (when some pre-service teachers were restricted to the sample activities previously provided by the teacher), in the second demonstration lesson, all the pre-service teachers created original proposals. This shows that, by the end of the course, the pre-service teachers expressed greater knowledge of key features of instructional materials. In general, during the two mock lessons, the questions the pre-service teachers formulated and considered appropriate for teaching through argumentation requested that the 'students' analyse the data to construct evidence, present justification, and analyse responses with respect to new data, favouring the manifestation of argumentative skills.

The analysis related to the category *actions that support teaching through argumentation* indicates the use of open questions as the main contribution to stimulating argumentative practices in the classroom. All of the pre-service teachers demonstrated knowledge of this action during Lessons 25, 26, and 27 (Table 2), because they sought to ask questions to the participants in order to motivate them to express their justifications, observations, and positions about the situations.

As for knowledge concerning the category *skills needed to conduct argumentative situations*, the pre-service teachers developed this knowledge regarding the use of socio-scientific issues by showing that they were able to create an argumentative environment in the classroom using socio-scientific issues. This is because, even though the lesson was only a simulation, and there were few participants (four mates and the teacher educator), they were able to: (i) promote argumentation in general; (ii) draw attention to the possibility of multiple answers; and (iii) use evidence to support the statements. On the other hand, the pre-service teachers showed limitations in their skills related to teaching chemical content through argumentation.

Discussion of results: characteristics of knowledge for teachers' action through argumentation

In order to illustrate the discussions generated from our results, in this section, we discuss three key issues: *evidence*, *justification*, and *skills needed to conduct argumentative situations*. The elements *evidence* and *justification* were selected because they have been highlighted in teacher training programmes focusing on argumentation reported in the literature (McNeill & Knight, 2013; Simon et al., 2006). The decision to present the discussion regarding the *skills needed to conduct argumentative situations* was based on the fact that this knowledge exemplifies a pedagogical aspect necessary for argumentation-based teaching context.

Evidence

The knowledge about evidence shown by the pre-service teachers can be analysed in view of the structure of the argument and its mobilisation in dialogical situations. We can think about the structural meaning of an argument based on the elements that comprise it. Therefore, as other authors have stated (Jiménez-Aleixandre, 2010; McNeill & Knight, 2013; McNeill & Pimentel, 2010), we recognise evidence as a support in the generation of arguments. In this sense, the pre-service teachers demonstrated an understanding of the concept and the role of evidence in constructing conclusions because, when planning their lessons, they were all at some point concerned with providing evidence that could be used by the participants to construct their responses. Furthermore, during the explicit teaching of argumentation, they were able to present evidence for the chemical knowledge and to employ this in constructing their arguments.

The dialogic dimension of argumentation relates to situations of persuasion or convincing an audience (Jiménez-Aleixandre & Erduran, 2008), or to situations in which consensus is established on the strength of a statement among an audience (Driver et al., 2000). Considering the role of evidence in this dimension, our data indicate a dichotomy between the results. On the one hand, the pre-service teachers were able to use evidence in order to convince or to strengthen an argument during the discussions of the activities conducted by the teacher educator. For example, at some times during the discussions of the activities, the consensus among the pre-service teachers was obtained through discussion between pairs focused on the evidence relating to the situation in question. On the other hand, they exhibited limitations in the use of evidence in the dialogical arena when they acted as teachers in the final mock lessons and needed to use evidence to

persuade the 'students' in relation to the scientific knowledge. However, in the context of this study (an undergraduate teacher preparation programme), we understand that the use of evidence in the dialogical dimension of argumentation depends on other aspects beyond the conceptual understanding of evidence (e.g. the experiences in conducting argumentation-based teaching situations and in reflecting on these situations) and on the knowledge of skills that support argumentation-based teaching.

Justification

In the McNeill and Knight (2013) study, the authors observed that the teachers experienced difficulties in understanding the meaning and the role of justifications in arguments. At the end of the course, the teachers improved their understanding about the element justification, but its use in science lessons continued to challenge the teachers. In our study, in general, the pre-service teachers did not have difficulties understanding the meaning of justification and using it when participating in the activities provided by the teacher educator. This was so because, during the course, the pre-service teachers (i) expressed only doubts or difficulties related to justification in the introductory lesson (Lesson 2), except for Lara; and (ii) provided indications that they had understood the role of justification in the elaboration of conclusions.

Although we do not have access to more detailed information on the education process experienced by the teachers investigated by McNeill and Knight (2013), we think that such different results are due to the previous experiences that the pre-service teachers who participated in our study had. In other pedagogical courses related to chemistry education, the pre-service teachers who participated in our study had discussed the constructivist teaching approach, mainly that knowledge has to be built by students with the help of the teacher, and that it is of pivotal importance to present justifications to the knowledge that is being taught. Therefore, those pre-service teachers were used to think about the reasons associated with each chemical topic when elaborating teaching activities.

Skills needed to conduct argumentative situations

Regarding the skills needed to conduct argumentative situations, we observed that teachers' skills to create and conduct argumentative environments in the classroom was linked to whether the teaching context was a scientific or a socio-scientific one. In our view, this difference may be linked to the nature of the problems discussed in each of them. Socio-scientific issues allow the generation of arguments that are based on scientific knowledge as well as everyday knowledge. On the other hand, in a situation where one is teaching chemistry-related content, (i) not all arguments can be considered to be appropriate during the entire teaching process, and (ii) the argumentative process developed with the students requires that the teachers master the concepts, since the teaching of chemistry-related content requires the use of specific evidence, presentation of coherent justifications, and convincing students of the validity of scientific statements against ad hoc hypotheses. As a consequence, it seems plausible to argue that limitations on the ability of those pre-service teachers to conduct argumentative situations with students derive from their limitations of the CK involved in the teaching situations.

Conclusions

In this paper, we analyse the development of the *knowledge for teachers' action through argumentation*, by exemplifying the analysis of some of the categories proposed to characterise it. As (i) the influence of the explicit teaching was not homogeneous among such categories, and (ii) the knowledge for teachers' action through argumentation is characterised from many aspects (Figure 1), it was impossible to reach a single conclusion. Therefore, we present our conclusions focusing on each of the elements/categories concerning argumentation (written in italics) and, in each case, we emphasise particular aspects of teacher's knowledge for acting through argumentation (written in inverted commas). In so doing, we highlight the extent to which the explicit teaching of argumentation analysed in this study contributed to the development of the pre-service teachers knowledge for actions through argumentation.

With regard to the element *evidence*, we found that the explicit teaching of argumentation contributed to learning among the pre-service teachers in terms of 'the use and meaning of evidence in constructing statements'; in other words, in terms of its roles in the structure of the argument. This is because, initially, the pre-service teachers demonstrated that they were unaware of possible evidence for scientific knowledge. However, throughout the course, they showed that they recognised and understood the role of evidence in generating arguments, and expressed less doubt about the meaning of evidence. Additionally, the pre-service teachers, on occasion, related discussions of the texts on the subject of evidence with the situations experienced in the activities. For example, in discussing specific evidence for a case, Lara related the concept to Activity 3, where no evidence could be considered specific. This influence also became clear in the instructional materials designed by the pre-service teachers because, in general, they designed materials involving data collection that had the character of evidence, or inserted data that could be used in constructing evidence. For example, Isis and Maria brought together a variety of data that could be used as evidence for the concluded cause of hair breakage in the activity from their first mock lesson (Lesson 11, Table 2).

Another contribution of the explicit teaching of argumentation to the development of the pre-service teachers knowledge on evidence refers to their 'learning about presenting evidence to support scientific claims', and 'mobilising specific scientific evidence for the phenomena under investigation'. Initially, they showed difficulties understanding what would be evidence for chemistry-related knowledge, as occurred in Activity 2. In addition, in this same activity, some of the pre-service teachers did not mobilise evidence that was specific to the chemistry-related claim being analysed. However, in the final mock lessons (Lessons 25, 26, and 27, Table 2), the pre-service teachers (except for Isis and Rachel) created proposals that presented specific evidence for the investigated phenomena.

Besides concluding that the explicit teaching of argumentation contributed to the learning of those pre-service teachers about evidence in the structural environment, that is, about its role and significance in constructing arguments, we conclude that this teaching made less of a contribution to knowledge about evidence with respect to its 'use in situations of persuasion or establishment of consensus'. This is because the pre-service teachers were able to use evidence to establish consensus during discussions in the activities, or to persuade a pair that had a different idea. However, during the mock lessons, they had difficulties mobilising evidence to persuade the 'students' when

discussing the validity of the scientific knowledge, or they did not discuss the evidence that the 'students' presented. This may have been caused by the lack of teaching experience among the pre-service teachers (a characteristic of all of them), or may be associated with the fact that knowledge about evidence for teaching situations is dependent on other factors, such as the skills for conducting argumentative situations.

With regard to the element *justification*, we concluded that the explicit teaching of argumentation contributed to the learning of pre-service teachers in relation to 'the role and the meaning of justification in constructing arguments' – that is, in relation to the structural dimension of an argument. In the final mock lessons, the pre-service teachers were able to mobilise the justifications for scientific knowledge. We emphasise that, throughout the pedagogical courses that were specific to the area of chemistry teaching, they had opportunities to develop some PK. This included knowledge about the idea of teaching chemistry from a constructivist perspective, in which knowledge is constructed jointly with students and, during this process, the theoretical models related to scientific statements are mobilised. In addition, they had the opportunity to plan lessons aimed at teaching chemistry-related content based on the constructivist perspective during their supervised internships. Therefore, we conclude that the contribution of the teaching on argumentation in relation to presenting justifications for scientific statements was boosted by the pre-service teachers' previous experiences with the perspective of constructivist teaching, since, in another context, they had thought (even indirectly) about the importance of presenting the theoretical models that supported scientific statements, that is, justifications.

We also conclude that teaching the knowledge of *the skills related to generating alternative theories and counter-argumentation* did not occur in a completely explicit manner in the situation under study. This was so because, even though the pre-service teachers had opportunities to exercise their skills and to experience activities that encouraged mobilisation of these skills (e.g. Activity 4, Table 2), they were not involved in reflections on this knowledge and their contributions to the teaching of science. Consequently, we cannot conclude which were the real contributions that the explicit teaching of argumentation might have on the learning of these skills in teaching situations.

As for *the ability to refute*, the explicit teaching of argumentation that we analysed herein helped the pre-service teachers to learn about 'the meaning of this skill'. On the other hand, we had difficulty drawing conclusions about the contributions of explicit teaching to 'mobilising the ability to refute in persuasive situations'. This is because the pre-service teachers were able to produce rebuttals during the classroom discussions, but had difficulties generating rebuttals in simulated teaching situations. With this in mind, we cannot conclude to what extent the explicit teaching of argumentation contributed to the development of knowledge about refutation in dialogical situations.

Turning to the pedagogical domain of the knowledge for teachers' action through argumentation (left side of Figure 1), an important contribution of the explicit teaching of argumentation to the knowledge of *teaching strategies* is learning about 'the use of socio-scientific issues in teaching'. It contributed significantly to the development of this knowledge among those pre-service teachers because all of the proposals they presented for the first mock lesson (Lessons 11 and 12, Table 2) involved the use of socio-scientific issues. Furthermore, we found that the pre-service teachers were able to mobilise most of the knowledge about argumentation, especially with regard to the meaning of the

elements, in their design of materials focused on socio-scientific issues. This is an important contribution and an advantage of the initial teacher education programme that we analysed, because it represents an expansion of the possibilities that the pre-service teachers have to contribute to their future students' learning in the social context. When we analysed the initial teacher training programme presented by Zembal-Saul (2009), we noticed an emphasis on the role of argumentation in the scientific context. In that study, there is no discussion about the importance of argumentation for science teaching from a perspective of developing citizenship, which is present in the whole programme analysed in this study.

The explicit teaching of argumentation also contributed to the development of knowledge about *instructional materials that favour teaching through argumentation*. This is because, at some point, all of the pre-service teachers designed instructional materials that were well suited to the proposal of teaching through argumentation. In other words, the materials they produced involved (i) open problems with the possibility of different answers, (ii) collection of data that could be used in constructing evidence, and (iii) mobilisation of the subjects' argumentative skills. More specifically, the contribution to the knowledge of instructional materials was progressive, that is, throughout the course, the pre-service teachers demonstrated an evolution in the instructional materials they designed. This conclusion is supported in the finding that the materials designed by the pre-service teachers for the first mock lesson (Lessons 11 and 12, Table 2), although consistent with the perspective of teaching through argumentation, were very similar to the activities proposed by the teacher educator until that point. On the other hand, in producing the materials for the final mock lesson (Lessons 25, 26, and 27, Table 2), the pre-service teachers showed greater 'autonomy in creating authentic material'.

Additionally, the explicit teaching of argumentation contributed to the development of *actions that favour teaching through argumentation* in terms of the 'use of open questions to stimulate argumentative practice in the classroom'. This is because, in the mock lessons (Lessons 11, 12, 25, 26, and 27), all of the pre-service teachers questioned the participants in order to encourage them to express their observations, justifications, and their positions concerning the situations that were being analysed. However, just as with the knowledge of *justifications*, we recognised that this contribution may be linked to the perspective of constructivist teaching, which presupposes the involvement of students in the teaching-learning process – which can occur through open questions. Therefore, we conclude that previous learning about constructivist teaching boosted the contribution made by using open questions.

With regard to *the ability to conduct argumentative situations*, it was possible to infer the development of the pre-service teachers' knowledge only from the mock lessons (in which this skill could be demonstrated), because during the other lessons, they did not express any doubts about or understanding of it. The analysis undertaken in this study also supports the conclusion that the contributions made by the explicit teaching of argumentation about this element were different for the socio-scientific and scientific contexts. For instance, during the mock classes in the socio-scientific context (Lessons 11 and 12, Table 2), all of the pre-service teachers, with the exception of Lara and Rachel, were able 'to promote argumentation in general', 'to highlight the possibility of multiple answers', and 'to use evidence to support their arguments'. However, in the scientific

context, the pre-service teachers had difficulties using the evidence presented by the 'students' in mobilising possible evidence for curricular knowledge. Therefore, it seems that the development of skills for conducting argumentative situations is related to the educational context.

By taking all the conclusions discussed in this section together, it becomes clear that the knowledge for teachers' action through argumentation is a complex construct, since it implies in teachers learning not only about structural elements of argumentation, but also about the teaching approaches or strategies to promote argumentative situations, as well as how to use them in science education. Therefore, it seems impossible to both promote the development of such knowledge through an individual activity and analyse it from a single criterion (or even few criteria). Such a complexity may also justify why the studies discussed in the initial sections of this paper – that were the first conducted in the area – emphasise only some elements of argumentation and/or some aspects of teachers' knowledge. In this sense, some relevant implications of our study emerge.

Implications

Argumentation-based science teaching requires teachers to assume their roles as agents responsible for the development of argumentative practice in the classroom. To do so, teachers have to develop educational knowledge related to this educational perspective. This means that during teacher preparation programmes, the teaching of argumentation has to be associated with a perspective of education that seeks to build knowledge with the students, rather than to transmit scientific facts. More specifically, we point out that explicit discussions about argumentation should occur in training courses, whether in-service or pre-service, after teachers understand both their role as mediators of the construction of scientific knowledge and the importance of students' understanding of science as a social enterprise.

Still concerning the structure of teachers' professional development focusing on argumentation, our analysis indicates that the explicit teaching of argumentation analysed in this study significantly contributed to the conceptual learning of the elements of argumentation, but had less of an impact on developing knowledge about these elements in teaching situations. Therefore, we emphasise how important it is that the teacher educator reflects with the pre-service teachers on the situations related to mobilising knowledge about evidence, justification, and argumentation skills for situations involving persuasion and establishment of consensus. In this way, the pre-service teachers can become aware of the importance of these elements to argumentative practice, which can help them to develop their knowledge of argumentation beyond the conceptual dimension.

With regard to teacher education and research in this area, a significant contribution of this study is the proposal of the construct *knowledge for teachers' action* with relation to argumentation. *Knowledge for teachers' action through argumentation* is related both to the teacher's understanding of the nature of the argumentative practice, that is, to the knowledge that the teacher needs to promote and conduct argumentative situations, and to effectively teach science from an argumentative approach. Such skills are significant

in educational contexts because, from the development of them, it is possible to establish or investigate which PK is linked to other scientific practices. For example, knowledge for teaching actions through modelling could involve understanding the meaning of models, understanding how modelling is performed in science, knowledge of instructional materials that support the involvement of students in knowledge-building processes based on modelling, the ability to formulate questions that encourage students to reflect on their models, and so on. Therefore, initial teacher training courses could structure teaching around educational approaches and strategies related to scientific practices by focusing on this dimension of knowledge related to the object of the teaching. In this way, the pre-service teachers could learn about the teaching approaches or strategies, as well as how to use them in science education. This could help them acquire a good basis of knowledge that would allow them to plan and apply argumentation-based teaching approaches more securely in regular teaching situations.

Considering (i) the nature of knowledge developed in initial teacher preparation programmes; and (ii) the fact that this knowledge is linked to the development of the students' cognitive skills, we emphasise the possibility of investigating and characterising such knowledge as *knowledge for teachers' action*. In doing so, we understand knowledge developed during initial teacher training as a primary stage of teachers' knowledge, or as a basis for the development of this knowledge. This is because teachers in initial training need opportunities to practise the mobilisation of such knowledge in real teaching situations, and time to reflect on these experiences. Therefore, real teaching experiences and reflections about these experiences are essential factors for teachers to understand how to apply this knowledge at other times during their teaching practice. Our data support this idea, because it gave us evidence that the knowledge of argumentation expressed by the teachers during their initial teacher education programme was not 'stable'. In other words, the pre-service teachers were able to mobilise their knowledge of argumentation in discussions with the teacher educator and with their peers but, in simulated teaching situations, they had difficulties or limitations in mobilising this knowledge. For example, the pre-service teachers were able to propose rebuttals during the classroom discussions, but when they conducted their mock lessons, that is, when they acted as teachers, they had difficulties refuting the ideas given by the 'students'.

In addition, similarly to the work by Zohar and Schwartzer (2005), this study draws attention to the fact that we need to critically examine theoretical references when the goal is to access, evaluate, or characterise educational knowledge in relation to knowledge about cognitive skills. That is to say, it is essential that we rethink the knowledge necessary for teachers when their teaching aim is to develop their students' knowledge or skills that go beyond scientific content. In this sense, the use of the construct *knowledge for teachers' action* seems promising in scaffolding analysis of teaching knowledge developed during initial teacher education programmes.

Notes

1. A comprehensive view of science is viewed as the idea that knowledge is a product of an ongoing process of judgement, examination, comparison, and evaluation of competing explanations (Kuhn, 1991), and that it is influenced by social-historical-economic-political issues.

2. The Argue-WISE material was based on sociocultural theories of learning, and proposes student engagement in constructing arguments based on the Toulmin's model (Toulmin, 1958).
3. For more details about the framework, see Zembal-Saul (2009).
4. According to Mortimer and Scott (2003), authoritative discourse is centred on only one point of view, and there is no discussion of the different ideas. In science teaching, authoritative discourse is focused on the scientific point of view.
5. The dialogic discourse (or approach) occurs when distinct points of view can be expressed, and all of them are considered to be equally valid (Mortimer & Scott, 2003).
6. In this case, *theoretical–practical* knowledge relates solely to what is taught in the training programme. In our view, this knowledge will only be *practical* if it is transposed into real teaching situations.
7. Contrary to the characteristics of teacher training courses in other parts of the world, in Brazil, it occurs in 4 years course divided into eight 4,5-month terms. During the first four terms, students attend classes in areas focusing on the development of chemistry content and other scientific content (physics, mathematics, etc.). From the fifth to the eighth terms, students continue to take chemistry content courses, but also take courses in general pedagogical knowledge and areas of pedagogical content that are specific to chemistry teaching.

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