



Analysis of Teachers' Knowledge on Argumentation: A Study of Portfolios of Chemistry Pre-service Teachers

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Abstract

This study aims to analyze which teaching knowledge pieces on argumentation are mobilized by pre-service chemistry teachers in their teaching portfolio when those pre-service teachers have experienced a course in which teaching argumentation was explicit; the study also aims to evaluate the contributions of using the portfolio in forming future teachers' knowledge on argumentation; lastly, what those contributions would be. A set of *a priori* categories and also categories emerging from our data were used to analyze the pre-service teachers' portfolios. The results show that the pre-service teachers demonstrated teaching knowledge related to logical-structural aspects of argumentation, teaching strategies, and materials that support argumentation in the classroom. Moreover, they expressed reflective teaching knowledge on those elements, which all support the argumentation. The conclusions of this study suggest the expression of all this knowledge can be related to the combination of building portfolios with the explicit context of teaching training programmes throughout the entire course. In addition to the fact that the portfolios have had the potential to map argumentative teaching knowledge, they also offered support to the expression and development of knowledge on this topic.

Keywords TEACHERS' KNOWLEDGE • ARGUMENTATION • EXPLICIT TEACHING • INITIAL FORMAL TRAINING OF TEACHERS • PORTFOLIO

Análise de Conhecimentos Docentes Sobre Argumentação: Um Estudo dos Portfólios dos Licenciandos em Química

Abstract

Os objetivos deste estudo são: analisar quais conhecimentos docentes sobre argumentação são mobilizados por licenciandos em Química em seu portfólio ao vivenciar uma disciplina cujo ensino de argumentação foi explícito; e avaliar se há contribuições do uso do portfólio para compreender os conhecimentos sobre argumentação desses futuros professores e quais são elas. Para isso, categorias *a priori* e emergentes dos dados foram utilizadas para analisar os portfólios dos licenciandos. Os resultados demonstram que os futuros professores de Química manifestaram conhecimentos docentes relacionados a aspectos estruturais-lógicos da argumentação, as estratégias e aos materiais instrucionais que sustentam a argumentação em salas de aula. Eles também expressaram conhecimentos docentes reflexivos sobre aspectos estruturais-lógicos da argumentação, estratégias e materiais instrucionais que apoiam a argumentação. As conclusões deste estudo sugerem que a manifestação de todos esses conhecimentos pode estar associada ao ato de conjugar a construção de portfólios ao contexto de ensino explícito de argumentação ao longo de toda a disciplina. Assim, além de os portfólios terem tido o potencial para mapear os conhecimentos docentes argumentativos, eles ofereceram também suporte à expressão e ao desenvolvimento de conhecimentos sobre essa temática.

Palavras-chave CONHECIMENTOS DOCENTES • ARGUMENTAÇÃO • ENSINO EXPLÍCITO • FORMAÇÃO INICIAL DE PROFESSORES • PORTFÓLIO

Introduction

In the last 20 years there has been an increase in the number of national and international publications about argumentation in the teaching of science (e.g., Duschl & Osborne, 2002; Zembal-Saul, 2009; Venville & Dawson, 2010; Ogan-Bekiroglu & Eskin, 2012; Martins & Macagno, 2022; Martins, 2022). This is because teaching supported by argumentation can contribute to science-learning as well as to the development of the argumentative capacity of students. Such learning may contribute to the educational objective of forming citizens who act in our society by proposing and analyzing solutions and positions based on arguments founded in the scientific knowledge. These actions have the potential to transform our society, making it fairer or, in other words, less unequal (MEC, 2018).

Given the importance of argumentation in teaching, the Common National Curriculum Base (CNCB) (MEC, 2018), a document that defines the essential learnings students must develop throughout Basic Education, presents such practice as one of the general competences of Education:

To argument based on facts, data and reliable information, to elaborate, negotiate and defend ideas, point of views, and common decisions which respect and promote human rights, socio-environmental conscious and responsible consumption at the local, regional and global levels, with ethic-positioning when taking care of themselves, others and the planet (MEC, 2018, p. 9).

For this type of argumentation to be promoted during science classes, a teacher must, during their initial or continued formal training, experience argumentative practices and have the opportunity to develop teaching knowledge and argumentative skills (McNeill & Knight, 2013; Zembal-Saul, 2009).

The documents Common National Base for the Initial Training of Basic Education Teachers (CNB-Formation) (MEC, 2019) and Common National Base for the Continuing Training of Basic Education Teachers (CNB-Continuing Formation) (MEC, 2020), both recently homologated, also express practically the same competences of CNCB, stating that the teacher must be able to demonstrate argumentations skills. Yet, we noted that nowhere in these documents is there a mention of which pieces of knowledge the teacher must have in order to be able to promote and conduct argumentative discussions in their classrooms. Therefore, such introduction and discussion aspects are at the discretion of each university or teacher college program, and also of continuing studies programs in Brazil.

Several scholars in the field of Science Education have investigated the argumentation of teachers (e.g., Simon et al., 2006; Lourenço & Queiroz, 2020) and students (e.g., Venville & Dawson, 2010; Ogan-Bekiroglu & Eskin, 2012; Martins & Justi, 2019). However, there are still only a few studies on the teaching knowledge of argumentation demonstrated by pre-service teachers in their initial training in science programs, in which argumentation has been explicitly approached, that is, with clear guidelines regarding this scientific practice throughout a discipline or a course (e.g., Zembal-Saul, 2009; Ibraim & Justi, 2016).

Therefore, besides addressing the aspects related to argumentation in the curriculum of formal training of teachers in the sciences, it is also important to discuss the tools used to evaluate the knowledge of pre-service teachers regarding argumentation.

There are a number of tool that can provide such evaluations; these include for example, interviews, questionnaires, and teaching activities. Such tools have often been used by the aforementioned scholars to understand the argumentation abilities of teachers and their knowledge regarding this scientific practice. Nevertheless, in none of those studies or in others available in the literature, the portfolio was never used to comprehend the teaching knowledge about argumentation demonstrated by pre-service chemistry teachers in initial formation programs in which teaching argumentation was an explicit component.

The portfolio is a tool that can be utilized to document, register, and organize the procedures and learnings so to make it possible the evaluation of knowledge demonstrated by the students. Additionally, a portfolio allows the subjects to reflect on their learning process, highlighting, for example, the aspects of ease, difficulty, as well as the importance of the themes studied. Such reflection is seen as an opportunity to mobilize and develop knowledge and abilities (Collins, 1992). In this way, the portfolio has a dual function: it provides learning of a theme in which the subjects regulate and recognize their learning process, and it also can serve as an evaluative tool.

In light of this discussion, it can be hypothesized that a portfolio can work in favor of pre-service chemistry teachers, causing them to reflect, and to manifest their abilities and knowledge about argumentation when they take part in learning processes on this topic. From these reflections, it is possible to comprehend the teaching knowledge regarding argumentation in a deeper and more contextualized fashion. This can therefore contribute to the identification and understanding of other teaching knowledge about argumentation that are different than the ones found in the Science Education literature. Therefore, this study aims to evaluate which pieces of teaching knowledge on argumentation are demonstrated by pre-service chemistry teachers in their portfolios when they experienced a course in which teaching argumentation was performed. From this analysis, the aim was to evaluate whether there are, and what will be the contributions of using portfolios to understand the knowledge on argumentation demonstrated by these future teachers.

Theoretical Rationale

Argumentation in Science-Teaching and the Initial Formal Training of Teachers

Jiménez-Aleixandre (2010) asserts that argumentation can contribute to the objective of forming scientifically literate citizens through science education and describes five aspects by which argumentation contributes to this process. One of these aspects is the formation of critical subjects, which allows students to substantiate their ideas or opinions. When they do that, they have the opportunity to comprehend the reasoning behind their choices, which can lead to them making responsible decisions.

Additionally, such scientific practice provides support for the students to comprehend the “whys” of what they know and how they know it, which contributes to the understanding and establishment of the relation between the scientific concepts, and, consequently, to a deeper learning of these concepts (Duschl & Osborne, 2002; Venville & Dawson, 2010; Duschl, 2017).

Argumentation can also create conditions for the students to perform scientific work, because it provides them the chance to experience some scientific practices during the elaboration, evaluation, legitimization, and communication of the scientific knowledge that is produced. Thus, they actively act in building their ideas in an analogous way to that of scientists (Duschl, 2017).

Finally, this scientific practice can provide science learning, i.e., the comprehension of processes involved in building scientific knowledge, the influences exerted to it, and the influences it exerts in our society. Such processes involve argumentative situations that take into consideration the evidence, justifications, and analyses of alternative positions (Duschl & Osborne, 2002; Duschl, 2017).

Despite these contributions of argumentation towards the teaching of science, it can be said that these can only exist if the teacher is capable of creating the proper environments for the practice to be promoted and conducted, aiming to allow students to argue and evaluate this process and its product (the argument) (Ibrahim & Justi, 2018). Thus, there is a consensus in the Science Education community about the need of teachers in initial and continuing formation to be provided with the opportunity to experience these argumentative practices and to develop knowledge related to argumentation (Zemal-Saul, 2009; McNeill & Knight, 2013; Ibrahim & Justi, 2018), because, otherwise, they would possibly face barriers to insert it into their classrooms, or it is possible that argumentation would not be worked on at all. On the other hand, there is currently no consensus regarding the impacts of the explicit versus implicit approaches (the latter being without direct and discursive guidance regarding the relative knowledge about argumentation, and with the experiencing of argumentation situations during teaching) on argumentation in the development of knowledge that support teachers and future teachers to promote learning through argumentation in their science classrooms (Zemal-Saul, 2009; Ozdem et al., 2013; Ibrahim & Justi, 2016).

In this study, a defence is put forward regarding the explicit approach of argumentation because it has been shown to be more effective in the development of knowledge of argumentation by teachers and pre-service science teachers, compared to the implicit approach (Zemal-Saul, 2009; Ozdem et al., 2013; Ibrahim & Justi, 2016). This is due to the fact that the explicit perspective contributes to teachers and pre-service teachers when comprehending the role of an argument, and how it may be possible to favor argumentative situations in a classroom based on different teaching strategies and activities.

In our literature review, we found that only the studies by Zembal-Saul (2009) and Ibraim and Justi (2016) investigated the explicit approach of argumentation in the initial formation of science teachers when they analyzed the teaching knowledge about argumentation demonstrated by future science teachers. Therefore, more studies on this perspective are necessary.

Zembal-Saul (2009) investigated how pre-service science teachers comprehended science teaching through argumentation and its practices in order to promote this type of teaching over the course of a semester. The author used different tools to collect the data: questionnaires, interviews and the observation of the classes. During the course, the student-teachers had the opportunity to (i) experience the investigative teaching of some scientific-curricular contents; (ii) analyze the discourse that permeates teaching through argumentation; and (iii) plan and execute activities that support the use of arguments, elaboration of conclusions based on evidences, and the involvement of students in science language.

This author concluded that the future teachers developed knowledge about the role(s) of evidence and justifications in building arguments and scientific knowledge. On the other hand, most pre-service teachers were not capable of favoring and conducting the argumentation with the objective of building scientific-curricular knowledge, that is, simplified in relation to scientific knowledge, and that students are expected to build within the school environment. Though this study discussed the knowledge held by teachers about argumentation, it was performed in a more general form, one without a detailed mapping of these bodies of knowledge.

In contrast, such mapping was conducted in the research by Ibraim and Justi (2016). These authors elaborated a model to characterize the knowledge of teachers about argumentation named Knowledge for Teaching Action on Argumentation in order to investigate pre-service chemistry teachers in initial formation part of a course where teaching argumentation followed an explicit approach. They used the observation of classes, in addition to their field notes to collect the data. According to the authors, the teacher must have knowledge of argumentation: i.e., knowledge about the structure of an argument, the argumentative capacities, and the different situations where argumentation is supported. The teacher must also have knowledge of the pedagogic aspects in the context of teaching argumentation, that is, about the teaching strategies and the instructional materials that can support argumentation in the classroom, as well as they must have had to develop the abilities needed to conduct argumentative situations and know-how to engage students in argumentation through a teaching strategy previously chosen. The results of this study indicated that the pre-service chemistry teachers developed the conceptual knowledge about the elements of an argument, the teaching strategies, and the instructional materials. On the other hand, they faced difficulties to mobilize such knowledge to promote and conduct argumentative situations.

Both Zembal-Saul (2009) and Ibraim and Justi (2016) assert that the explicit teaching of argumentation can also favor studentteachers and teachers in order to engage in a reflection that can support the development of deeper knowledge about argumentation. Nonetheless, there are no guarantees that this occurs often and by different subjects in class, due to this process not occurring in real time and requiring that it also be performed individually, since every subject comes with its own singularities (Zeichner, 2008). Thus, the observation can be seen as a limiting factor because it only allows the researcher to observe what happens in situ, during classes (Cohen et al., 2011). The questionnaire and the interview can also limit the comprehension of the teaching knowledge on argumentation, once those are constituted by fixed questions that prevent subjects from expressing themselves (Cohen et al., 2011 as cited in Martins & Macagno, 2021). Additionally, the semi structured interview has questions that can be modified, but there is a tendency of the interviewee to respond what they believe that the interviewer would like them to respond (Sandoval & Millwood, 2005 as cited in Martins & Macagno, 2021). As a consequence, the use of such tools (all or some), as done by Zembal-Saul (2009) and Ibraim and Justi (2016), indicates that specific pieces of knowledge on argumentation might not be mapped, developed, and/or manifested.

The fact that the pre-service teachers in both studies have had difficulties to use the knowledge developed on argumentation during the real situations or in mock-teaching scenarios, can also be related to the lack of or reduced number of individual explicit reflective moments about the conceptual knowledge related to argumentation during their formation. This has possibly influenced the non-mobilization of other pieces of knowledge and the establishment of deeper and conscient relations that provided support to a teaching practice that favors argumentation in classrooms.

On the other hand, we believe that the portfolio combined with an explicit approach for argumentation can favor that reflections be frequent and individual, and as a consequence, so, too, is the mobilization of different knowledge about argumentation. There is no record, however, in the literature of the use of this tool to comprehend, specifically, the teaching knowledge about argumentation mobilized by pre-service chemistry teachers in initial formal training programs where teaching argumentation followed an explicit approach. This article will address this gap.

Portfolio and the Formal Training of Teachers

In order to have elements that highlight the potential of a portfolio as a tool used to understand the teaching knowledge on argumentation (aspects associated with the objectives of this study), it is appropriate to ask: what is a portfolio? And what are its contributions to a teacher-formal training?

According to Hernández (1998), the portfolio is presented as a continent of different types of documents (personal notes, class experiences, essays, learning checkpoints, connections with other topics outside of school, visual representations, etc.) which provide evidence of the knowledge built, the strategies used, and the willingness of whom creates it to continue learning (Hernández, 1998, p. 100).

Considering this definition, the portfolio can be seen as an instrument that allows for the reflection of whoever produces it by carrying a dual function: a facilitation of learning, and a means of evaluation. This is because when one individual builds their portfolio, there is the possibility that they might be transforming, changing, or rethinking their learning strategies, and potentially adjusting their pedagogic practices when they register their experiences.

Some studies have discussed the uses of portfolios in the formal training of teachers (e.g., de Veloso et al., 2020; Firme & Galiazzi, 2014; Nascimento et al., 2011; Villas Boas, 2005). These studies systematically present what is necessary when using portfolios for the formal training of teachers, with the goal of evaluating, for example, the writing of teachers and the level of advancement of that writing during formal training in relation to the different types of knowledge. With these pieces of information, it is possible to comprehend, for instance, the conceptions and perspectives of the pre-service teachers, as well as their teaching knowledge and their depth of understanding. From that, there is evidence to reflect, analyze and propose changes to the current programs of teacher training.

Furthermore, these studies point out that portfolios can also cause teachers to reflect and analyze the process of their own learning, which may contribute to the development of abilities and knowledge. In Veloso et al. (2020), for example, the pre-service chemistry teacher expanded her knowledge about how science develops and how its related products work from the use of portfolios associated with this study case.

Thus, we consider the portfolio as a political instrument because it depicts the human traits of the teacher undergoing formal training and under professional development. From this document, the pre-service teacher has the possibility to bring up different actuations that must be respected — when read, corrected, researched — and considered when registering their history and life experiences, formative trajectories, moments, moves, comprehensions, teaching knowledge, decisions, and opinions. Such aspects influence the pedagogical practices of the pre-service teacher. Therefore, we are convinced that the portfolio can be used in the analysis of teaching knowledge about argumentation mobilized by future chemistry teachers in a course where teaching argumentation followed an explicit approach.

Nonetheless, for the portfolio to be able to provide contributions as presented here, it is necessary to establish guiding criteria with the objectives one expects with such tools given that it is possible to use a portfolio to comprehend/evaluate different aspects — as previously presented, for example, in Zanellato (2008).

Methodological Aspects of the Research

Data Collection Context

Data were collected between February and March of 2021 during a mandatory course of Chemistry Teaching offered in the last term of Teachers College (Chemistry) of a public university in the countryside of Northern Brazil. As the syllabus for the course is wide-ranging (allowing for different focuses) and only requires the elaboration and presentation of course elements for teaching chemistry developed from the knowledge developed throughout the class, the Professor developed a personalized program to introduce and discuss argumentation in teaching chemistry/sciences.

This course was structured from logical, rhetorical, and dialectic perspectives of argumentation, given that we believed that this is the way the future teachers could develop a wider point of view regarding this topic, as also pointed out by Ibraim and Justi (2018).

Generally speaking, the logic focuses on the product of the argumentation, that is, on the argument in terms of the establishment of reasoning patterns in order to produce plausible arguments. Its goal is to judge the argument.

Regarding the rhetoric, its focus lies in the argumentation process, in the understanding of situations of argumentative efficiency also through unspoken social rules to persuade others or a specific audience in particular. Thus, the gestures, the intonation and expressions of good arguments are fundamental for the persuasion to happen.

Finally, the focus of the dialectic is on the argumentation procedure so that a critical discussion takes place with the elaboration and expression of the best arguments. For that, the context, who speaks and when they do, the relevance of the speech, the contributions of the interlocutors in order for the dialogue to occur and evolve, are all essential (Wenzel, 1990).

Nevertheless, we assume that the comprehension of these perspectives alone would not be sufficient to structure the class in a way that favored the pre-service teachers to develop their knowledge on argumentation. Thus, some elements found in Zembal-Saul (2009) and Ibraim and Justi (2016) were implemented in class: planning and developing instructional materials that support argumentation on Basic Education; analysis of videos of Basic Education classes to learn about teaching strategies related to argumentation; and exercises to understand the concepts and role of statements, justification and evidence.

Thus, articulating all these aforementioned aspects, we planned a course that aims to enable, from the logical, rhetorical and dialectical perspectives, (i) the understanding of what argumentation is; (ii) the understanding, importance and contributions of argumentation for the formation of science teachers and scientifically literate citizens; (iii) the experience of activities that can support the development of argumentative skills; (iv) the understanding, elaboration, analysis, and conduction of instructional materials

that can foster argumentation in science classrooms; and (v) the understanding, appreciation, and use of strategies and situations that enable argumentation in science classrooms.

The course was also planned considering remote teaching due to the COVID-19 pandemic. This means that it took place virtually, mainly through the Google Meet platform.

At the meeting 1¹, which took place in February, there was a presentation and to explain the course program and the forms of evaluation, which included the portfolio. In addition, it was discussed what argumentation entails from the perspectives of pre-service teachers, the importance and contributions of argumentation to the formation of scientifically literate citizens and science teachers, and the argumentation from the perspectives of formal and informal logics.

Meetings 2 and 3, which also took place in February, were made available for the execution and discussion of Activity 1: "Do we really know chemistry?" In this activity, which is focused on the logical perspective, several statements associated with chemical content are presented (such as melting and boiling temperatures remaining constant during changes in the state of substances) and must be supported by evidence and justification.

At the March meetings (4–7), the Activity 2: "Do students and teachers make arguments in science classrooms?" was conducted and discussed. This activity consisted of the analysis of a high school class in which they discussed the use of a dataset in the construction of evidence, alternative explanations and the appreciation of specific evidence to assess whether or not the remains in question belonged to Copernicus. The analysis of the course must consider: if, how, and when the teacher favored argumentative situations and the objective of each one of them; if the teacher produced arguments consisting of statement, evidence(s) and justification(s); and if, how, and when the students developed arguments consisting of the statement, evidence(s) and justification(s) and the purpose of each of the arguments. Furthermore, actions must be proposed, described and justified by the pre-service teachers to favor the argumentation of the class examined, considering the logical perspective. Such actions must be different from those performed by the analyzed teacher.

Continuing in March, meetings 8, 9 and 10 were carried out to conduct and discuss Activity 3: Getting to work (part 1), whose objective was to build an argumentative activity in the logical perspective involving the thematic properties of materials. In this construction process, the following should be explored in detail: (i) the relevance of the theme; (ii) the teaching context; (iii) the purpose of the questions (i.e., how they favor the elaboration of arguments that present statements, justifications and evidence, and the learning of the selected curriculum content); and (iv) how the activity conducted was aimed at learning chemical content and students' argumentative engagement.

¹ Each meeting lasted approximately 2 horas and 30 minutes.

At meeting 11, there was a presentation and discussion of instructional materials that support the argumentation and learning of chemical contents in the logical perspective. Some of the unpublished materials were prepared by the course teacher, others are activities extracted from books and articles in the area of science education, such as the candle activity, which involves a chemistry problem whose questions have the potential to provide opportunities for the elaboration of arguments, refutations, counterarguments and alternative theories (Correa, 2011). Subsequently at meeting 12, a review of theoretical aspects of argumentation, while articulating them for practice, was carried out, followed by the introduction and discussion of the rhetorical perspective of argumentation. Both meetings took place in March 2021.

Activity 4: Debate Time was conducted and discussed at meetings 13, 14, 15 and 16 that took place in April. This activity consists of the video analysis of a Mock Jury on the research funding on transgenic materials that took place in a high school class. In this analysis, pre-service teachers should identify the evidence, justifications, and inference in the students' statements, as well as assess whether the evidence and justifications as strong or weak, and whether the inferences as relevant or irrelevant. In addition, they should judge the context and rhetoric of students' speeches as relevant/irrelevant and weak/strong, respectively. From this, a verdict must be produced.

At meeting 17, the dialectical perspective of argumentation was introduced and discussed. Meetings 18, 19 and 20 involved the conduction and discussion of Activity 5: "Do students and teachers favor argumentative situations in science classrooms?" In this activity, transcripts of a high school class on intermolecular interactions were provided for pre-service teachers to analyze from a dialectical perspective. The analysis of the class should reflect upon the following: if, how, and when the teacher favored argumentative situations and the objective of each one of them; and if, how, and when students produced arguments and questions to support their idea(s) and evaluated those of their teacher and classmates. In addition, actions should be proposed, described, and justified in order to support the argument of the examined class. Such actions should be different from those made by the course teacher. All these meetings took place in April 2021.

In May, at the 21st meeting, a review of the theoretical aspects of argumentation studied in the class and linked to practice was carried out.

Finally, meetings 22 to 27 were used to conduct and discuss Activity 6: "Getting to work (part 2)." This activity consisted in the elaboration of an investigative didactic sequence (IDS) that contemplated the perspectives approached during the class (Logic, Rhetoric, and Dialectics)². IDS should involve: (i) a theme that addresses chemical

² The course teacher had initially planned that the pre-service teachers would plan and teach simulated classes of one of the IDS activities since classes in the regional school board were suspended when the course was started. When activity 6 was carried out, classes had been resumed through remote teaching for just over a month and a half. As schools were still adapting to online teaching, there was no opportunity for the pre-service teachers to teach classes in a real context. In addition, because the pre-service teachers did not have access to a webcam, the simulated classes ended up not being taught. As an alternative, the professor asked the pre-service teachers to propose discussions to encourage the argumentation and learning of the selected content(s) for each IDS activity, and to present the IDS to their classmates

content; (ii) the relevance of the theme for the teaching of Chemistry; (iii) the teaching context; (iv) the general objective of the IDS; (v) the specific objectives of each activity that makes up the IDS, in terms of learning the content(s) and contributing to the development of students' argumentation; and (vi) how discussions should be carried out to encourage argumentation and learning of the selected content(s). These meetings also took place in May 2021.

It should be noted that during the first class, the professor informed the pre-service teachers on the individual and weekly (or fortnightly, depending on the deadlines for activities) elaboration of their portfolios. In this context, she explained that portfolios should include, for example, the following: the activities they did; the descriptions and reflections related to the development and discussions of each one of the activities, with the possibility of also making explicit the relationships with themes that go beyond the classroom; descriptions and reflections of the discussions of the course with possible connections with situations that transcend the formal learning spaces, and other aspects deemed important for the teacher training.

Weekly or biweekly, the Professor provided feedback on the portfolios produced by pre-service teachers on the Google Drive platform. The feedback was largely associated with the understanding of the process of building a portfolio, since, until the beginning of the class, none of the pre-service teachers in the class had written this type of text. Initially, many pre-service teachers reported the classes in their portfolios. However, based on the Professor's feedback, the portfolios became more reflective and explored argumentation, teacher training, and other related topics. We believe that these guidelines were essential to enable future teachers to regulate and recognize the process of their own learning and to evaluate what they have learned or not from the classes and activities, especially regarding argumentation.

Course participants

The course professor holds a bachelor's degree in Chemistry, a Master's and a Doctorate in Science Education. Her final product in her bachelor's thesis, Master's dissertation, and Doctoral thesis addressed the argumentation in science teaching. It would follow that she possesses the necessary knowledge to insert and discuss argumentation in science teaching. In addition, she herself has experience as a public chemistry teacher, having taught for seven years. Such experience can foster discussions on the adequacy of the pre-service teachers' proposals for this level of education.

The six pre-service chemistry teachers had already taken all the specific chemistry courses and courses on general pedagogy. They had also already taken most of the subjects of chemistry teaching. Therefore, they had sufficient knowledge to carry out the activities of the course in question and to engage in discussions originated in the course and elsewhere. We emphasize that none of these student had previous contact with argumentation in chemistry/science teaching as a subject of study until the moment of this class.

For this research, four pre-service teachers were selected; their fictitious names are Isa, Jade, Alex, and Eric. Only these students fully met certain criteria that could enable a broader and deeper analysis of teaching knowledge on argumentation; which is essential to discuss the objectives of this work, namely: (i) participated in all meetings; (ii) did all the course activities; and (iii) made reflections related to the arguments in the texts of their portfolios that provide evidence their understanding of this scientific practice.

Data Analysis

We analyzed the portfolios produced by the pre-service teachers: Isa, Jade, Alex, and Eric.

To understand the teaching knowledge on argumentation mobilized by students, we used the content analysis proposed by Bardin (2006). This means that, initially, the portfolios were read analyzed in detail, and fragmented into units related to the topic studied: teaching knowledge on argumentation. Thus, the parts of the texts in which the pre-service teachers expressed and explored some level of knowledge on argumentation were configured as units of analysis (Table 1).

The units of analysis can be defined a priori when the categories already exist and/or from the analysis itself when emerging categories are created (Bardin, 2006). In this study, some categories were defined a priori based on research by Zembal-Saul (2009) and Ibraim and Justi (2016). However, during the analysis, these categories were better defined, some of them were lumped or excluded according to content similarities, and then received new category names. They are: **Teaching knowledge of structural-logical aspects of argumentation; Teaching knowledge of strategies that can favor argumentation in the classroom; Teaching knowledge regarding the mastery of the ability to argue; and Teacher knowledge about instructional materials that can support classroom argumentation.**

Other categories emerged from the analysis, such as: **Reflective teaching knowledge of structural-logical aspects of argumentation; Reflective teaching knowledge of strategies that can favor argumentation in the classroom; Reflective teaching knowledge regarding the mastery of the ability to argue; and Reflective teacher knowledge about instructional materials that can support classroom argumentation.** These were refined and those showing similarities in content were lumped together or excluded. Therefore, the categories of this work were created in a mixed way.

Table 1. *Categories of analysis of teaching knowledge on argumentation with their definitions*

Teaching knowledge on argumentation	Definitions
Teaching knowledge of structural-logical aspects of argumentation	Knowledge about the elements that constitute an argument (affirmative, justification, and conclusion), how they are related, their functions, and/or other elements that are part of the process of its construction and evaluation (e.g., context, gestures, and intonation).
Reflective teaching knowledge of structural-logical aspects of argumentation	Reflections on the importance and/or difficulties of understanding the elements that constitute an argument (affirmative, justification and conclusion), how they are related, their functions, and/or other elements that are part of the process of its construction and evaluation (e.g., context, gestures and intonation).
Teaching knowledge of strategies that can favor argumentation in the classroom	Knowledge about strategies (such as types of argumentative situations, questions, teaching activities) that can favor students to engage in argumentation and produce arguments.
Reflective teaching knowledge of strategies that can favor argumentation in the classroom	Reflections on the importance and/or difficulties (limitations) related to strategies that can favor students to engage in argumentation and produce arguments.
Teaching knowledge regarding the mastery of the ability to argue	Knowledge about the mastery of the ability to argue.
Reflective teaching knowledge regarding the mastery of the ability to argue	Reflections on the importance and/or difficulties (limitations) related to the mastery of the ability to argue.
Teacher knowledge about instructional materials that can support argumentation in the classroom	Knowledge about: materials and/or their central characteristics that support classroom argumentation; and/or the development of materials that support classroom argumentation.
Reflective teacher knowledge about instructional materials that can support argumentation in the classroom	Reflections on the importance and/or difficulties (limitations) of producing and using instructional materials that support argumentation in the classroom.

After categorizing the data, another table was produced, which presents the frequency of teaching knowledge on argumentation expressed by the pre-service teachers. Based on this analytical process, we were able to explore the knowledge on argumentation mobilized by future teachers, and consequently the contributions of the portfolio instrument.

Results and Discussion

In Table 2, we present the frequency of teaching knowledge on argumentation mobilized by the pre-service teachers in their portfolios throughout the course whose teaching argumentation followed an explicit approach.

Table 2. *Frequency of teaching knowledge on argumentation expressed by future teachers in their portfolios*

Teaching knowledge on argumentation	Isa	Jade	Alex	Eric
Teaching knowledge of structural-logical aspects of argumentation	3	7	2	3
Reflective teaching knowledge of structural-logical aspects of argumentation	9	5	4	2
Teaching knowledge of strategies that can favor argumentation in the classroom	5	4	5	9
Reflective teaching knowledge of strategies that can favor argumentation in the classroom	2	3	3	2
Teaching knowledge about instructional materials that can support argumentation in the classroom	5	6	5	4
Reflective teaching knowledge about instructional materials that can support argumentation in the classroom	9	1	1	1
Teaching knowledge regarding the mastery of the ability to argue	0	0	0	0
Reflective teaching knowledge regarding the mastery of the ability to argue	1	1	1	1
Total	34	27	21	22

From Table 2, we observed that the pre-service teachers did not express the teaching knowledge regarding the mastery of the ability to argue. Upon assessment, it can be said that such knowledge was not manifested because these future teachers did not have an understanding of their own ability to argue and/or they did not feel safe to express themselves about such topic. According to our second hypothesis, we believe that this reflects a traditional teaching in which the error or limited mastery of a content or skill is considered to be a negative. However, understanding the learning process itself, recognizing what they know and what they do not know, creates conditions for students to regulate their learning, i.e., to learn how to learn (Osborne, 2014).

Teaching knowledge of structural-logical aspects of argumentation was mobilized by all pre-service teachers (see Table 2). In fact, the future teachers expressed knowledge about the elements that constitute an argument, how they are related and the functions of each of them.

During the discussion of activity 1, I understood that the statement would be a theory or point of view that is defended, and the evidence is given by the observation of facts or data that will support the statement. It is worth remembering that evidence is not limited to empirical data, representations and theories are also valid. And regarding justification, it is the reason or cause that will support a statement and connect it to the evidence. However, great care must be taken not to confuse justification with explanation. When talking about justification, one seeks to show why and how a certain idea is plausible by presenting reasons and causes, but about explanation, in turn, one seeks to show why and how something happened by exposing the facts and data, that is, seeking to clarify a situation or phenomenon. (Pre-service teacher Jade)

In this passage, Jade expressed knowledge on statement, justification, evidence, and explanation. Regarding the evidence, the student expressed an adequate view that evidence can have a theoretical and an empirical nature, which is an interesting aspect. This is because, generally, students have a positivist view on this aspect, that is, they summarize the evidence to empirical data (Sandoval & Millwood, 2008). We believe that the use of a portfolio associated with activities and discussions aimed at the explicit teaching of argumentation contributed to the teacher student having several opportunities to reflect on this aspect, which contributed to her development and explanation of that point of view.

Another relevant aspect to be discussed is the differentiation between justification and explanation made by the future teacher. Such an understanding is not easy, given teachers, students and even researchers have difficulty distinguishing explanation from justification, since such movements are strongly intertwined in discourses, as pointed out by Berland and McNeill (2012). According to Jade, her understanding was only possible due to the discussion of Activity 1, whose objective was to discuss the argument from the perspective of logic. In the study by Ibraim and Justi (2016), the authors express that the pre-service teachers had great difficulty in differentiating, justifying from explaining, even after several explanations and some activities. In our view, the mobilization of this knowledge by Jade and other students is associated with the different opportunities they had throughout the class: carrying out activities and discussions aimed at the explicit teaching of argumentation, and the writing of portfolios. According to Veloso, Mendonça and Mozzer (2021), the use of a portfolio when teaching during teacher formation can help students to develop, explain, and/or expand knowledge.

Reflective teaching knowledge of structural-logical aspects of argumentation was frequently manifested by all pre-service teachers (see Table 2). We believe that the recurrence of this knowledge was due to the difficulty that students had when differentiating statements from evidence and justification during the experiencing of activities in which they had to present evidence and justifications (activity 1) and analyze argumentative situations proposed by teachers and developed by students (activities 2, 3, 4 and 5). This difficulty contributed to them realizing the importance of understanding such elements and others (gestures, intonation, and context), as can be seen in Alex's excerpt:

I liked activity 4, as I was able to reflect on the importance of understanding the elements that constitute the argument. But just understanding its definition is not enough to assess students' arguments, as the analysis can be less accurate. So that this does not happen, it is also essential to understand how such elements were expressed and related by the students, considering their intonation and gestures, and the context in which their speeches were expressed. (Pre-service teacher Alex)

In this passage, Alex expressed reflections on the importance of understanding the elements that constitute an argument, how they are related, how they were expressed, accounting for the gestures and intonation made by students in a given context. By mobilizing this teaching knowledge, the pre-service teacher seems to have understood that having knowledge of some aspects of the logical structure of argumentation is not sufficient in assessing students' arguments. Both in Zembal-Saul (2009) and of Ibraim and Justi (2016), the authors point out that future teachers were able to understand structural-logical aspects of argumentation. In none of these studies, however, did the analyzed sample mobilize reflective teaching knowledge about the structural-logical aspects of argumentation: context, gestures and intonation, as observed not only in Alex's portfolio, but also in those of the other pre-service teachers. We assessed that the use of the portfolio may have also contributed to the mobilization of this knowledge, given that this instrument allows for explicit and individual reflective moments, which can lead to the construction and recording of new relationships between the situations experienced and the knowledge learned in an attempt to establish coherence with teaching activities, as pointed out by Hernández (1998).

The **teaching knowledge of strategies that can favor argumentation in the classroom** was also recurrently manifested by the pre-service teachers (see Table 2). Here, they expressed knowledge about strategies that possibly enable students to engage in argumentation and produce arguments.

In the analysis of a teacher's class (activity 2), I understood that providing activities to be done in groups can encourage and value the argumentative interaction between individuals who have different ideas, as well as respect for diversity. In addition, in this same activity, I noticed that the action of providing the space also considering the student's idea can favor engagement in argumentation. But this alone is not enough, it is also necessary to elaborate questions that favor the elaboration of justifications, presentation of evidence, opposition of hypotheses with the data collected after some experiment, for example, as it can help students to be convinced and rethink their ideas. (Pre-service teacher Eric)

I have learned that several strategies can be used in argumentation during the class. For example, in activity 4, at different times, students used aspects of rhetoric (fallacies, attacks, intonation, gesticulation, emotional appeal, rhetorical questions) to counter-argue and reinforce their ideas. (Pre-service teacher Eric)

In these excerpts, Eric mobilized several strategies that can support argumentation in the classroom. In the study conducted by Ibraim and Justi (2016), future teachers only expressed some strategies that support the argument during the process of elaborating activities aimed at this objective, at the end of the course. We believe that the activities and discussions aimed at the explicit teaching of argumentation and the use of the portfolio instrument to write/record about the learning process provided the pre-service teachers with opportunities for individual and collective explicit reflective moments, which provided support for them to express possible teaching strategies that support the argument.

Reflective teaching knowledge of strategies that can favor argumentation in the classroom was expressed by all four future teachers (see Table 2). In this, the pre-service teachers expressed the importance and the difficulties related to the strategies that have the potential to engage students in argumentation and produce arguments.

From the activities, I have reflected how important it is for us teachers to know the argumentative strategies and to know how to use them, because otherwise, even though using an excellent activity that could support several interesting argumentative dialogic situations, the argumentation may not be favored. This occurred in the class we analyzed (activity 5). The teacher used an activity that supports argumentation, but her discussion did little to cause the students to argue. (Pre-service teacher Jade)

From the discussion of activity 3, I have reflected that it is essential that the teacher also has knowledge about the strategies that can favor students to argue in the classroom, because without such knowledge, situations in which students question the contents may not be created, as well as discussions about the arguments that the students produced may not be promoted. (Pre-service teacher Alex)

In these excerpts, Jade and Alex expressed the importance of teachers having knowledge about strategies that support argumentation, because, otherwise, they would not be able to create and promote a teaching by argumentation in their classrooms, even when instructional materials that aim to favor argumentation are used. In addition, Alex expressed argumentation as a way for students to question the contents. This means that, for him, argumentation offers conditions for students to elaborate and evaluate arguments, and to criticize the knowledge presented to them, an aspect previously pointed out by Duschl (2017). In our view, the moments of explicit reflection on argumentation that took place collectively (carrying out and discussing activities) and individually (building portfolios throughout the entire class) favored the pre-service teachers to express the aforementioned knowledge.

The **teaching knowledge about instructional materials that can support argumentation in the classroom** was expressed with some frequency by all four future teachers (see Table 2).

The investigative sequence begins by asking students to predict which food is acidic and which is not, and then explain why based on their knowledge. The prediction and arguments should be written in student notebooks. After that, they must taste the food, compare the results with the predictions that were recorded in the notebook and elaborate new arguments, if necessary. In this way, the arguments developed in this activity, based on the writing in the table about the predictions of food acidity and food tasting, can favor students to compare and evaluate their answers, which must be based on arguments. (teacher student Isa)

Subsequently, in the second activity, students must, through an experiment that uses red cabbage juice as an acid-base indicator, identify whether the same foods brought in the previous activity are acidic or not. The questions in this activity help students make predictions (which must be justified), analyze the evidence, and elaborate possible explanations based on arguments. (teacher student Isa)

Activity 3 expected students to compare their conceptions before and after the experiment on the relationship between the acidity of foods and their conservation. For this, they must produce and evaluate arguments in order to explain the phenomena to be observed, that is, apple with lemon, apple with vinegar, apple in the fridge and apple on top of the fridge. The argumentation in this activity is for students to realize that, in addition to refrigeration (refrigerator) and other commonly known methods, such as pasteurization, addition of salt, among others, acidic foods (vinegar and lemon) are excellent natural antioxidants used to slow down the rotting process. (Pre-service teacher Isa)

Finally, activities 4 and 5 aim to put into practice all the knowledge developed by students in activities 1, 2 and 3 by asking them to propose solutions based on arguments for Clara's disease. For this, a set of texts is made available to the students. Three groups are formed. While groups 1 and 2 must propose ways to treat Clara's disease, group 3, composed of students who will act as doctors, must evaluate the treatments proposed by groups 1 and 2. All groups must present evidence and justifications to support and to evaluate the treatments selected for Clara's case. (Pre-service teacher Isa)

In these excerpts, we note that Isa mobilized knowledge about the development of material that supports argumentation in the classroom by exploring in detail the characteristics of each of the activities of the investigative sequence that has the possibility of engaging students in argumentation, namely: elaborating justified predictions; analyzing the evidence; elaborating and analyzing possible explanations based on arguments; opposing predictions with results obtained; and proposing and analyzing solutions based on arguments. The richness of these details was also observed in the portfolios of the other future teachers.

We can say that the recurrence of this type of knowledge is related to the activities that produced instructional materials (activities 3 and 6) and their discussion, as well as the construction of the portfolio throughout the class, which contributed to the pre-service teachers having several occasions to reflect, register, and structure the procedures and their learning. As pointed out by Collins (1992), the portfolio tends to mobilize and develop knowledge by subjects.

On the other hand, the **reflective teaching knowledge about instructional materials that can support argumentation in the classroom** was least expressed by most future teachers in their portfolios (see Table 2). We believe that this may have happened because the students were already exhausted at the end of the class, mainly because activity 6 (last activity) demanded a greater effort from them to produce an investigative teaching sequence. In this sequence, pre-service teachers should present all activities that support the argumentation and learning of some chemistry content and explain the didactic guidelines on how to conduct each of them. In the following excerpts, this aspect can be detected:

Until now, I was excited about the elaboration of the didactic sequence. But right now, I am getting tired, because we have to produce a set of activities in a logical sequence that favors the students' engagement in argumentation, and propose how to conduct each one of them. This has required several meetings with my group and with the course Professor. (Pre-service teacher Alex)

Creating an investigative teaching sequence was challenging and quite tiring, but the final product turned out to be very good, receiving many accolades. I think about using it when teaching. (Pre-service teacher Eric)

The writing of the sequence is getting a little 'boring' shall we say, as we are a little tired. So, there is no longer that euphoria from the beginning. However, we are very confident about what we have written, studied and researched a lot about it, and we believe that the Professor and colleagues will like it. (Pre-service teacher Jade)

Regarding the **reflective teaching knowledge about instructional materials that can support argumentation in the classroom**, this can be observed, for example, in the excerpts by Eric and Isa.

From activity 3, I could reflect on how the elaboration of material that supports the argumentation should be well thought out, because, based on it, the teacher can conduct argumentative situations that contribute to the student to elaborate arguments and conclusions, and to reason logically, about the idea they are advocating, that is, developing argumentative skills. This facilitates the understanding of scientific concepts, as argumentation requires students to have more organized thoughts regarding the contents. (Pre-service teacher Eric)

From activity 6 and its discussion, I realized that elaborating and using materials that support the argumentation, such as argumentative and investigative activities, is of paramount importance for teaching, especially for Chemistry, as it may favor students not to see this science as a puzzle where its parts do not fit. This is because, in addition to having the opportunity to express their prior knowledge, these activities can contribute to student to relate and use concepts consciously, as they need to justify their ideas and present evidence that supports them. (Pre-service teacher Isa)

In these excerpts, Eric and Isa expressed the importance of producing and using instructional materials that support argumentation in the classroom, associating them with science-learning and the development of argumentative skills, aspects also defended by Duschl (2017). The other pre-service teachers also mobilized this knowledge (see Table 2), but reflected on the difficulties of producing and using instructional materials that support the argumentation in the chemistry class.

Reflective teaching knowledge about instructional materials that can support argumentation in the classroom, as well as other reflective teaching knowledge, were not mobilized by the samples investigated in Zembal-Saul (2009) and Ibraim and Justi (2016). We assess that the manifestation of reflexive knowledge on argumentation by pre-service teachers is of salient importance, as it tends to contribute to making them aware of their knowledge, processes, and skills on argumentation. This can lead them to rethink their ideas and teaching actions that support teaching through argumentation. We believe that the act of combining the construction of portfolios with the entire context of explicit teaching of argumentation favored moments of constant individual and collective reflection for future teachers, which contributed to them expressing different reflective teaching knowledge.

Finally, the **reflective teaching knowledge regarding the mastery of the ability to argue** was expressed only once by each pre-service teacher (see Table 2). This low incidence may be associated with the fact that future professors have a low understanding of their own ability to argue and/or do not feel safe to express reflections on this topic. Such reasons are similar to those presented for teaching knowledge about the domain of the ability to argue. The knowledge in question is exemplified below:

From the discussion of activity 1, I could see that it is extremely important that I know how to argue, because without this I will not be able to properly conduct and promote argumentative situations when I am teaching. (Pre-service teacher Alex)

With the discussion of activity 5, I realized the importance of knowing how to argue, because this skill can support the process of conducting argumentative situations in classrooms, which can help in the formation of critical citizens. Without such ability, instructional materials that were created to favor argumentation, for example, may not fully fulfill their function. (Pre-service teacher Jade)

These excerpts show Alex and Jane's reflection on the importance of knowing how to argue in order to promote and conduct argumentative situations in classrooms. When this skill is not developed, future teachers may find it difficult to promote and conduct argumentation, as pointed out by some studies, such as Zembal-Saul (2009), McNeill and Knight (2013) and Ibraim and Justi (2018). We consider that the manifestation of this knowledge by future teachers is related to the same justification presented for the other reflective knowledge.

Final Considerations

In this study, we analyzed what teaching knowledge about argumentation is mobilized by pre-service chemistry teachers in their portfolio when experiencing a class where teaching of argumentation was explicit. The analysis carried out showed that the pre-service teachers manifested different knowledge about argumentation, namely: **Teaching knowledge of structural-logical aspects of argumentation; Reflective teaching knowledge of structural-logical aspects of argumentation; Teaching knowledge of strategies that can favor argumentation in the classroom; Reflective teaching knowledge of strategies that can favor argumentation in the classroom; Teaching knowledge about instructional materials that can support argumentation in the classroom; Reflective teaching knowledge about instructional materials that can support argumentation in the classroom; and Reflective teaching knowledge regarding the mastery of the ability to argue.** Some of these pieces of knowledge, those of a reflective nature, have not been observed as of yet in other studies that sought to understand teachers' knowledge on argumentation in initial training courses where teaching of argumentation was explicit. Thus, we assess that the manifestation of all this knowledge can be associated with the performance of activities and their discussions aimed at the explicit teaching argumentation and the act of producing the portfolio, which provided opportunities for future teachers to constantly reflect on individual and collective levels. These moments supported the clarification and development of knowledge, as can be seen in the results and discussion presented in the previous section.

In addition, we believe that the non-expression of **teaching knowledge regarding the mastery of the ability to argue** by all the future teachers was due to the following possible reasons: low understanding of students about the mastery of their own ability to argue and/or the lack of confidence in expressing about that topic.

The differences found in the frequencies of teaching knowledge on argumentation mobilized by future teachers are due to the way in which each subject internalized the knowledge on this theme and expressed it individually through the portfolio.

Based on this analysis, we assessed whether there are any contributions and what they are when using the portfolio to understand the knowledge about argumentation of these future teachers. Our results show that the portfolio has the potential to analyze the knowledge about argumentation expressed by future chemistry teachers, especially when the research aims to investigate the process, since it favored the identification

and understanding of their knowledge. The portfolio also has the potential to favor the development of knowledge when combined with the entire context of explicit teaching of argumentation, as presented and discussed throughout this paper. This is because it provides moments of constant individual reflection that generate contributions in the process of making ideas explicit and in the development of knowledge (Veloso et al., Mendonça & Mozzer, 2020; Firme & Galiazzi, 2014).

Despite the positive results that we obtained with the use of this instrument, we emphasize that our study did not aim, for example, to investigate how portfolios can contribute to the understanding of teaching knowledge on argumentation mobilized by chemistry teachers in initial formative training, which can contribute to understanding more deeply the scope and limitations of this instrument.

Therefore, in order for us to have more elements about this instrument and the teaching knowledge about argumentation, research must be carried out to understand the knowledge of pre-service teachers and teachers from different disciplines in the area of Natural Sciences and its Technologies about this scientific practice, both during the initial training programs and during continuing training programs, and within a teaching practice.

The results of these studies can support proposals and actions in the initial and continuing training of teachers to engage students in reasoning and in science-learning. In this sense, it becomes relevant to investigate the influence of methodological aspects used by teachers in the development of teaching knowledge about argumentation — something that lacks additional study in this area (Ibraim & Justi, 2018) and that can broaden the discussions on teaching actions that influence the learning conditions and the development of knowledge about argumentation by pre-service chemistry/science teachers.

We assess that such studies can generate contributions to the development of higher education curricula that aim to explicitly insert and discuss argumentation in science teaching.

Acknowledgments

The authors would like to thank God; the peer-reviewers and editors for their valuable contributions to this article; and to the teacher and pre-service teachers for allowing this study to be developed, and for engaging throughout the entire process. Finally, the authors would like to thank Carlos Barreto for translating this article to English language.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Compliance with Ethical Standards

The authors declare this study was conducted following ethical principles.
