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The Pedagogical Content Knowledge (PCK) of a Chemistry Student Teacher: An Experience in Pre-Service Education

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Abstract

The aim of this study was to analyze the development of the PCK of a Chemistry student teacher, from a university in southern Brazil, during teaching activities in the Supervised Internship. The theoretical basis adopted in this study was the PCK theory proposed by Shulman (1986, 1987) and some models that unfolded from it. Data collection occurred through audio recordings of the discussions that took place between the student teacher and the teacher educator during the planning of the teaching activities and after their implementation. These discussions were transcribed and the student teacher's speeches were analyzed based on discursive textual analysis. During planning, the mobilization of the student teacher's PCK had as a starting point the content knowledge, which supported the mobilization of other knowledge from the base, such as general pedagogical knowledge and knowledge of the context, influenced by teaching purposes and strategies and by the situations experienced with students. After the classes were taught, the PCK presented itself through a reflective process that gave rise to five categories: Learning, Participation, Planning, Teacher-Student Interaction and Pedagogical Content Mediation, particularities that were part of the PCK and that were expanded by the validation of the practice itself. Therefore, we defend that the development of the student teacher's PCK occurred in association between the integrative and transformative models proposed by Gess-Newsome (1999).

Introduction

Diniz-Pereira (2019) states that one of the dichotomies to be overcome in teacher education, in pursuit of professional teacher development, is the separation between teacher education and teacher work. Teacher professional development is defined by García (2009) as an individual and collective process that occurs in the long term as different types of opportunities and experiences are integrated, which take place in the work environment and at the school. The author frames it in the search for professional identity, in the way that teachers define themselves and others. Thus, this can be understood as a construction of the professional self, which evolves throughout their careers, and can be influenced by the school, reforms and political contexts, which integrate personal commitment, willingness to learn to teach, teacher beliefs, values, knowledge about the subjects they teach and how they teach them and past experiences. Therefore, professional identities configure a

complex tangle of histories, knowledge, processes and rituals (García, 2009). Therefore, discussing the inseparability of teacher education and teacher work in pre-service teacher education requires thinking about how undergraduate courses are organized and what actions have been carried out to promote the articulation of theory and practice throughout the teacher education process. For this, as pointed out by Broietti and Stanzani (2016), there is a need for teacher education based on the integration of different knowledge, through the articulation between theory and practice, in order to prepare future teachers with scientific quality and didactic principles for the exercise of teaching.

According to the Brazilian Resolution for Teacher Education, CNE/CP 02/2015, throughout the process of training teachers in basic education, effective and concomitant relationships between theory and practice should be guaranteed, both providing basic elements for the development of knowledge and skills necessary for teaching (Brasil, 2015). For this, we understand that it is necessary to guide teacher education based on an epistemology opposed to technical rationality, considering a training perspective with epistemology grounded in practice, which aims to train teachers as reflective professionals, as discussed by Schön (2000) . According to the author, reflective thinking can lead professionals to permanently discover forms of quality performance through the investigation and reflection of their own practice. This idea is also shared by Silva and Schnetzler (2008) who claim that reflection on one's own practice enables the future chemistry teacher to become a researcher in the classroom. In this sense, we understand that the Supervised Internship presents itself as a rich space for building knowledge for teaching through the articulation between theory and practice and reflection on the specific teaching situations experienced during the internship in the field schools, enabling the development of abilities to plan, implement, evaluate, reflect and build new understandings about teaching. It is on this path that we guide the construction of this work, which brings results of a doctoral research that presents as an investigative scenario the pre-service education of Chemistry teachers, in the context of the Supervised Internship.

The main focus of this research was to investigate the development of pedagogical content knowledge of a Chemistry student teacher during the planning and implementation of teaching activities in the teacher internship, with a view to the student teacher's professional development. For this, we take as support the theories of Shulman (1986, 1987) on the development of pedagogical content knowledge and the teacher's knowledge base. The aim of this study was to analyze the development of the PCK of a chemistry student teacher in carrying out teaching activities in the Supervised Internship.

Pedagogical Content Knowledge (PCK)

Shulman (1986) points out that specific content knowledge must be valued among teachers' knowledge and that this is at the center of their professionalization. We understand that the specificity of each discipline requires from the teacher skills and abilities, and also a set of knowledge to develop quality teaching practices that enables students to understand the content being taught. In this sense, Shulman (1986) explains that specific content knowledge is composed of three categories: Content Knowledge, Curriculum Knowledge and Pedagogical Content Knowledge. Content knowledge is defined by the author as "[...] the amount and

organization of knowledge per se in the mind of the teacher" (Shulman, 1986, p. 9).

Goes (2014) discusses that it is necessary to be clear to the teacher why a given content is central to a theme while other content can be adjacent to the same theme. In this sense, we interpret that content can encompass several concepts that can be classified as central or adjacent, according to the teacher's intentions and his/her goals for the teaching of each content. We understand, therefore, that Shulman (1986) refers to content knowledge both in terms of quantity and organization because this type of knowledge does not refer only to the accumulation of a set of concepts in the teacher's mind, which must be transmitted and accumulated in the students' minds, but it presupposes an in-depth knowledge of the existing connection between these concepts.

Curriculum knowledge refers to knowledge of the curriculum of subjects, the curriculum being defined by the author as "[...] a full range of programs designed for the teaching of particular subjects and topics at a given level [...]" (Shulman, 1986, p. 10). Thus, our understanding of this type of knowledge refers to the contents to be worked on at each level of education, as well as the methodological strategies and forms of assessment used. The third category refers to Pedagogical Content Knowledge which, according to Shulman (1986)

> [...] goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching. I still speak of content knowledge here, but of the particular form of content knowledge that embodies the aspects of content most germane to its teachability (p. 9).

We understand that this type of knowledge refers both to the way the teacher organizes, relates and delimits the content topics to be covered, as well as the way it is taught, so that students can understand it. In this sense, Shulman (1986) argues that PCK encompasses the understanding of the most varied forms of representation of the topics of a content, analogies, illustrations, examples and explanations, that is, ways of representing and formulating the content that make it understandable for others, as well as the knowledge of the students' understanding, that is, the conceptions that students of different ages and origins bring with them that influence the learning of the contents.

Shulman (1987) presents PCK consisting of two components: knowledge of representations of specific content and instructional strategies and the understanding of learning difficulties and the students' conceptions of a content (Fernandez, 2015). In our understanding, the first is revealed through knowledge about how the content can be organized, explained and discussed with students during classes, as well as knowledge of teaching strategies and methodologies that favor their learning and lead students to conceptual elaborations. The second is interpreted as the teacher's understanding of student learning, more specifically the way they relate to the content, demonstrating affinity and/or difficulty in understanding the concepts worked on.

That said, Shulman (1987) proposes a Knowledge Base of teaching, consisting of seven categories of knowledge, as listed below:

- Content knowledge;
- General pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter;
- Curriculum knowledge, with particular grasp of the materials and programs that serve as "tools of the

trade" for teachers;

- Pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding;
- Knowledge of learners and their characteristics;
- Knowledge of educational contexts, ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures;
- Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds (p. 8).

According to Shulman's theory, PCK stands out as an exclusive knowledge of teachers constituted by the combination of specific and pedagogical contents, which is at the heart of teachers' knowledge, thus, it is necessary for the teacher to master and transform the base knowledge into PCK. Therefore, PCK represents knowledge built from other knowledge bases, such as practical teaching experiences or a dialogue with the practice itself (Shulman, 1987; Fernandez, 2015). After Shulman's proposal, other PCK models were proposed, with Grossman (1990) who for the first time systematized the knowledge of the base and the PCK, as shown in Figure 1.

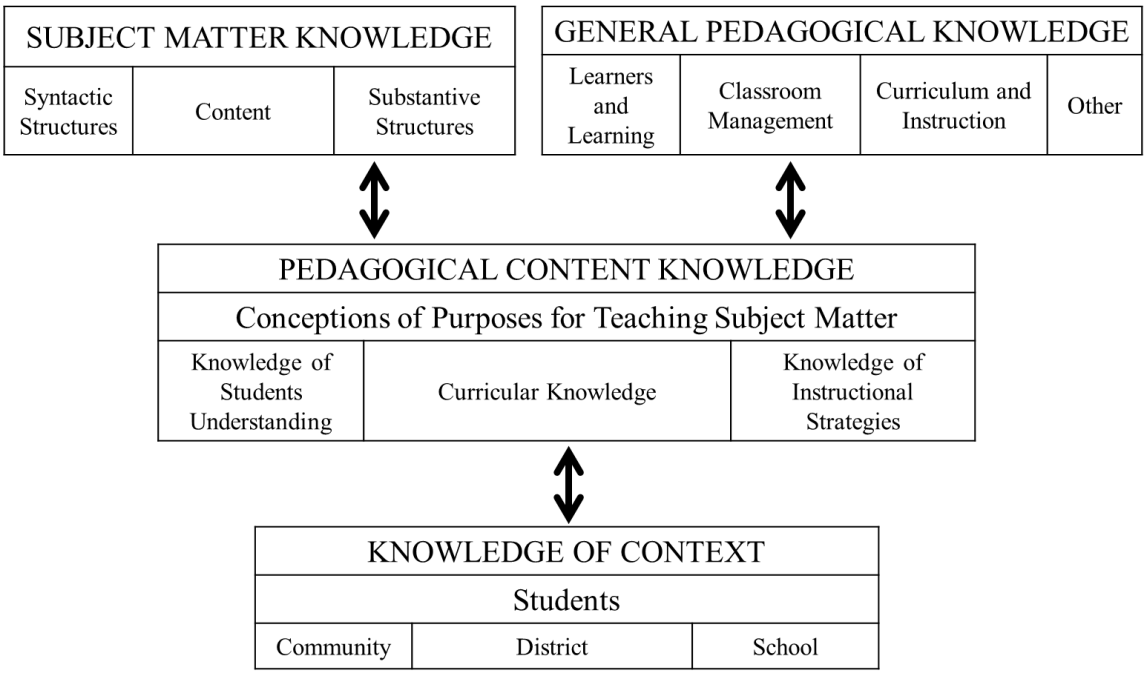


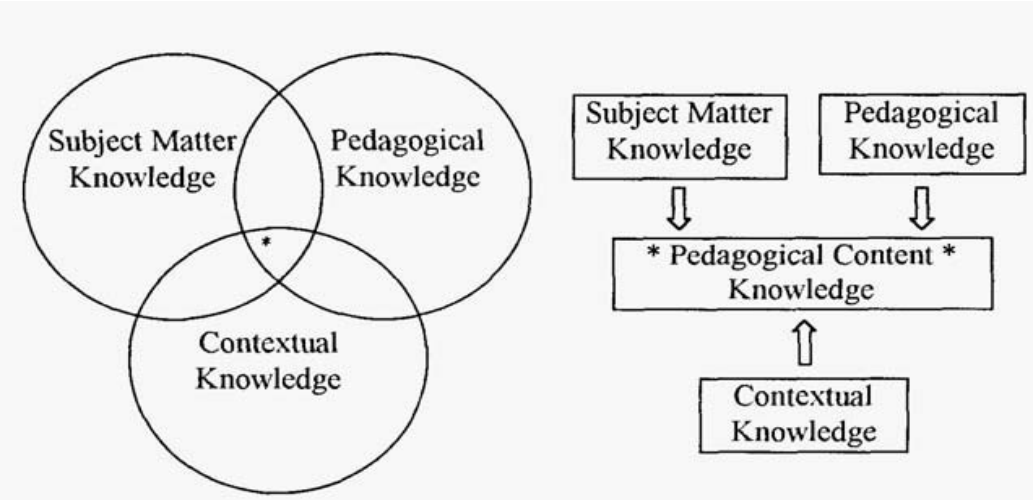
Figure 1. Model of Teacher Knowledge

Based on the seven categories proposed by Shulman, Grossman (1990) allocated four general areas of teacher knowledge as the pillars of knowledge for teaching: general pedagogical knowledge, subject matter knowledge, pedagogical content knowledge and knowledge of context. General pedagogical knowledge includes a body of general knowledge, beliefs and skills related to teaching. This body of knowledge includes knowledge relating to students and learning, classroom management, general principles of instruction, and the goals and purposes of education.

According to Grossman (1990): "Knowledge of content refers to knowledge of the major facts and concepts within a field and the relationships among them" (p. 6). In addition, the author also highlights the substantive and syntactic structures that encompass this type of knowledge, the substantives being those that refer to paradigms and research questions that affect the way a field of knowledge is constructed and organized. Syntactic structures include an understanding of the body of evidence within the discipline and how arguments and explanations from investigations are evaluated by members of the discipline (Grossman, 1990).

Knowledge of the context includes knowledge of the districts and school environment in which teachers work, the opportunities, expectations and constraints imposed by those environments, the "culture", departmental guidelines, and other contextual school factors that affect teaching activity. These spheres include knowledge of students, communities to which they belong, their families, their experiences, strengths, weaknesses and interests (Grossman, 1990). Grossman (1990) explains that PCK is composed of four components, that is, the purposes (knowledge and beliefs) about the teaching of specific themes at different levels of education; knowledge of students' understanding and conceptions of different topics within a content; knowledge of the curriculum and knowledge of instructional strategies and content representations. Therefore, the author places PCK as a central type of knowledge among general pedagogical knowledge, subject matter knowledge and knowledge of the context, subordinated to the four components presented. This reinforces Shulman's (1986) proposal that PCK is built and developed from the transformation of the knowledge base, therefore, its development influences and is influenced by such knowledge (Grossman, 1990).

Based on Shulman and Grossman's proposals and in an attempt to understand the nature of teachers' knowledge development, Gess-Newsome (1999) proposed two different PCK development models, which represent the extreme of a continuum: the Integrative Model and the Transformative Model, shown in Figure 2.



* = knowledge needed for classroom teaching

Figure 2. Two Models of Teacher Knowledge

At one extreme, PCK does not exist as a domain of knowledge and teacher knowledge can be more easily explained by the intersection of three constructs: subject matter knowledge (specific content), pedagogical

knowledge and contextual knowledge. In this case, the act of teaching occurs through the integration of these three domains, that is, it depends on the presentation of content to students in some context, using an appropriate form of teaching. This is the integrative model. At the other extreme, PCK is the synthesis of all the knowledge needed to be a teacher. In this case, the development of PCK takes place through the transformation of the three knowledge domains into a single form, a knowledge base necessary for the teacher's teaching practice. Therefore, PCK is understood as the knowledge base for teaching. This model is called transformative. In this model, the main point is not the development of knowledge domains, but how they become PCK in teaching practice (Gess-Newsome, 1999).

To explain the subtle distinctions between the two models, the author uses an analogy from Chemistry, comparing them to the processes of formation of a mixture (water with sand) and a compound (ammonia). When two materials are mixed, they can form a mixture or a compound, however, what differentiates one process from the other is the fact that in the mixture, the original materials remain chemically distinct and can be recovered by some physical process. According to Gess-Newsome (1999), the Integrative Model is analogous to a mixture such as water and sand, and the Transformative Model analogous to the reaction of ammonia formation from hydrogen (H_2) and nitrogen (N_2) gases. Both are present in teacher education processes. Regardless of the model, it is important that the basic knowledge is related and that the importance of knowledge domains for the development of PCK is recognized, as well as the experiences arising from teaching practices, which involves critical reflection, decision making, recognition of the students and the school context (Gess-Newsome, 1999).

Fernandez (2015) presents an overview of other PCK models portrayed in the literature, based on Shulman's proposal. The models are: by Carlsen (1999), by Morine-Dershimer and Kent (1999), by Rollnick *et al*. (2008), by Magnusson, Krajcik and Borko (1999), by Park and Oliver (2008), by Abbel (2008) and the most recent of them, the PCK Summit Model, proposed in 2012, at a conference attended by thirty groups of researchers in Science Teaching (Teaching of Physics, Chemistry and Biology) who work with PCK (Fernandez, 2015). In Hume, Cooper and Borowski (2019) we can find an updated perspective on the advancement of research on PCK in the education of Science teachers. The work presents the Refined PCK Consensual Model, proposed in 2016 based on the PCK Summit model, with the purpose of investigating the nature of PCK in Science education in a variety of Science education contexts. Thus, given the numerous possibilities to analyze the PCK of Science teachers in training, we emphasize that in this investigation we took Shulman's initial proposal and the first models that were developed from it as a theoretical basis (Grossman, 1990; Gess-Newsome, 1999) as presented in the theoretical foundation of this manuscript.

Method

The Context of the Investigation and Data Collection

The present investigation took place during Supervised Internship activities by Chemistry student teachers, specifically in the Teacher Internship. Such activities are part of one of the disciplines of the Licentiate Degree in Chemistry at a public university in southern Brazil, which are conducted under the guidance of the teacher

educator. It is an annual discipline of the last year of the Chemistry Education course - Licentiate Qualification, which includes activities done both at the university and in schools in the region, with a duration of 144 practical hours.

In this Teacher Internship, experimental classes are elaborated and developed, based on the principles of Investigative Experimentation and theoretical classes, which result in a Didactic Sequence (DS), supported by the specifications of the Three Pedagogical Moments approach. Investigative Experimentation is a teaching strategy to promote conceptual elaborations by students through phenomenological investigations and the formulation of hypotheses about a phenomenon that one seeks to understand (Souza et al., 2013). The Three Pedagogical Moments (3PM) is a thematic approach organized in three steps: Initial Problematization (IP), Knowledge Organization (KO) and Knowledge Application (KA), which has its theoretical bases in Paulo Freire's works about the importance of dialogue between the educator and the student, a fundamental aspect for the problematization of real situations for students (Delizoicov et al., 2011).

These activities provide the student teacher intern's contact with the school and its professionals, in order to promote the articulation between theory and practice, integrating the university and the school, and developing research related to the teaching of chemistry with high school students (Broietti & Stanzani, 2016). The discipline's routine includes fortnightly orientation meetings held at the university between each intern and the teacher educator. Therefore, data collection for this research took place in the orientation meetings for the planning and development of the Experimental Activity (02 hours of class) and a Didactic Sequence (04 hours of class) on the content of Solutions. During these meetings, the conversations between the teacher educator and a student teacher, here called Jane, were audio recorded and then transcribed for analysis. Since this investigation took place in Brazil, we emphasize that the communicative interactions between the teacher educator and Jane took place in Portuguese and were later translated to be included in this article.

Data Analysis

Textual Discursive Analysis (TDA) of Moraes and Galiazzi (2011) was used in this investigation to build meanings from a set of texts, the "corpus", here constituted by the transcriptions of the discussions that took place between Jane and the teacher educator during the planning, implementation and evaluation of the internship activities. Two sets of data were analyzed: 1-discussions that took place between Jane and the teacher educator during the preparation of the activities; 2-post discussions, which took place after the classes were taught at school. Both were submitted to each stage of analysis of TDA, namely: the deconstruction of the texts of the "corpus", the unitarization (in which units of analysis in each data set were identified); the establishment of relationships between unitary elements, categorization (which was constructed in an emergent way from the identified units of analysis); and, the capture of the new emerging in which the new understanding is communicated and validated, relying on the aforementioned literature that underlies the research (Moraes & Galiazzi, 2011).

From the categorization process, which was carried out using the inductive method (Moraes & Galiazzi, 2011),

in the first data set, categories related to content knowledge (CK, with 5 subcategories) and pedagogical content knowledge (PCK, with 2 subcategories) emerged. The second data set originated one category, the developed pedagogical content knowledge (coded as DPCK) in which five subcategories were organized: Learning, Participation, Planning, Teacher-Student Interaction and Pedagogical Content Mediation. The last stage of TDA, the capture of the emergent, expresses the understandings reached during the entire analysis process and is presented in the following topics.

Results

First Step of the Analysis - The Guidelines

The analysis of Jane's statements at this stage gave rise to the categories of Content Knowledge (CK) and Pedagogical Content Knowledge (PCK). Next, we present the analysis and interpretation of the student teacher's speeches, which allowed us to make inferences about the development of her PCK. To be listed in the text, the lines were numbered respecting the order of occurrence in the discussion with the teacher educator and were coded with the symbols "CC" for Chemistry Content, "EA" for Experimental Activity and "DS" for Didactic Sequence.

C1 to C5 (CK) – Chemistry Content

Categories C1(CK) to C5(CK) emerged from the student teacher's notes on the specific content – Solutions – and its conceptual organization in classes during the EA and DS.

> "[...] concentration calculation and classification into saturated, unsaturated..." (1_CC)

> "[...] do a DS with this type of problem to work on concentration, concentration calculations" (2_CC)

> "[...] then, in the experimental activity, you can work with the basics, solute, solvent..." (3_CC)

> "I was also in doubt about one thing; solubility would come in here too, wouldn't it? If you're going to see everything you have to work on solutions, there is the concept of density, solubility, a lot of things". (4_CC)

We identified from 1_CC to 4_CC that Jane presented knowledge both in relation to the content and its organizational structure, because while she exposes what she intends to work with in the EA and DS, the relationship she makes between the central concepts of the content of Solutions and other concepts is evident, concepts that may be related and that may arise in class discussions.Shulman (1986) tells us that content knowledge is revealed by the amount and organization of specific knowledge in the teacher's mind. This definition is interpreted by Grossman (1990) as the knowledge of the main concepts within an area of knowledge, in this case Chemistry, and the relationships between them. In our understanding, Jane demonstrated knowledge of the content of Solutions, which enabled the organization of the concepts to be addressed in the EA

and DS, as well as the construction of understandings about the existing conceptual relationships considering the content of Solutions.

C1(PCK) – Preparation of the EA

The subcategories of C1(PCK) refer to the elaboration of the EA, established based on the student teacher's considerations about the organization of the content from each item that constitutes an investigative experimental script. The theme used to contextualize the study of Solutions during the experimental activity was the high salinity in the Dead Sea, which supported the elaboration of the problem situation on the fact that people are unable to sink in its waters.

> "But can't it be that one doesn't sink in the Dead Sea?"; "But then it has to do with density too". (1_EA)

> "[...] I don't need to put anything related to density, right, because that's not the objective". "The second aim will be discussed at the time of practice". (2_EA)

> "So, then the solution becomes saturated, then you have to add more salt and it won't dissolve again"; "So, if we think about it, from then on we could work with the cork, right" (3_EA)

In the discussion of the concepts necessary to solve the problem situation (speech 1_EA) we clearly identified the integration between the chemistry content and the teaching strategy, which leads us to understand that the mobilization of the student teacher's PCK in the EA planning has as a starting point the content knowledge (Shulman, 1986). So, in the construction of the objectives and stages of the experiment, we verified even more clearly in the lines 2_EA and 3_EA the integration between specific content and the strategy of investigative experimentation, as they (student teacher and teacher educator) think about the objectives and stages of the experiment based on each topic of the content to be approached, revealing that the student teacher's PCK is completely linked to the content and its transformation into teachable content, as Shulman (1986) discusses.

Therefore, we begin to build an understanding that during the planning of the EA, the mobilization of Jane's PCK occurs with knowledge of the content as a starting point, linked to its teaching purposes and knowledge of instructional strategies and content representations, ideas that became clearer in the discussions about the elaboration of the problem situation, the objectives and stages of the experiment. The general pedagogical knowledge and the knowledge of the context are little evident in the speeches, perhaps because of the importance given to the content itself. Another important point is that in this planning phase of the EA, the student teacher did not present ideas regarding the understandings and conceptions of the students, one of the components of PCK presented by both Shulman (1986) and Grossman (1990).

Finally, we realized that the elaboration of the post-laboratory questions (speech 4_EA) occurs in the relationship between the intended understandings by the students and Jane's intentions with the planning, in which she perceives the relationship between all the components of the experiment script, as well as the

relationship between her intentions and the intended learning for the students.

> "[...] I will ask in the first question to define solute and solvent. "[...] how are we going to insert density in the discussion?" (4_EA)

Once again we verified that the mobilization of the student teacher's PCK is revealed through its purposes regarding teaching and knowledge of instructional strategies and content representations, supported by knowledge of the specific content (Shulman, 1986; Grossman, 1990). We understand that as the student teacher and the teacher educator build each part of the experiment script linked to the previous discussions, there is a deepening in the organization of the content based on the teaching purposes and the teaching strategy adopted, investigative experimentation. Therefore, we found that Jane's PCK during the preparation of the EA is supported by knowledge of the content and is revealed by its organization and integration to the adopted instructional strategy, taking into account its teaching objectives and the intended learning by the students.

C2(PCK) – DS Elaboration

The subcategories of C2(PCK) refer to the organization of the DS classes, built from Jane's notes on the organization of content in each pedagogical moment, as the Three Pedagogical Moments approach presupposes. The theme used to contextualize the content during the didactic sequence was the NaCl content in saline solution, which supported the construction of a problematization of the different units used to express the concentration of solutions.

> "[...] In one bottle it had 4%, in the other 4g/L and in the other 4mol/L. Then she [a student] asked if they tried each, if the taste would be the same for all three. I thought it was really cool and I thought about the possibility of us working on this". (1_DS)

> "[...] because all packages are 250, right. Then I was wondering if they weren't going to get a little confused. That's why I just put 2.25..." (2_DS)

During the elaboration of the 1st moment, we verified in speech 1_DS the mobilization of PCK in the sense of transforming the specific content into teachable content in the initial problematization (Shulman, 1986). Furthermore, we noticed that Jane is more proactive than in the elaboration of the EA, probably because she has already taught the experimental classes. This reveals some signs of the development of her PCK, as Shulman (1986) discusses. Even so, her concern with the specific content is recurrent during the planning, as we see in speech 2_DS.

It is observed that Jane, when elaborating the problem, paid attention to the questions that could be asked by the students during the class. As in the preparation of the EA, the mobilization of her PCK takes place, starting from the content knowledge that supports the elaboration of the initial problematization so that it gives rise to the discussion of the intended content in the second moment, evidencing its teaching purposes (Shulman, 1986;

Grossman, 1990). Such reflections by the student teacher show that her PCK during the DS planning is revealed both by discussions about the organization of the content based on the adopted approach, and by the concern with the students' conceptions and understandings, elements of PCK pointed out by Shulman (1986) and Grossman (1990).

In lines 3_DS and 4_DS, we verified the planning of the 2nd moment when Jane looks for everyday examples to contextualize the content and reflects on the use of mathematical formulas in carrying out concentration calculations.

> "So I'm going to use this example to explain m/m (mass/mass) and hydrogen peroxide to explain v/v (volume/volume)..." (3_DS)

> "[...] I don't know if I'll show them those formulas that also require them to calculate concentration, so they can get some practice..." (4_DS)

We noticed that in both lines, Jane's PCK continues to be supported by content knowledge, however, it is also based on the context when she searches for everyday products students know and on a teaching model of knowledge construction, when she reflects on the use of mathematical formulas, clearly evidencing the student teacher's beliefs and teaching purposes, elements that according to Grossman (1990) also support the PCK. And finally, we verified in the lines 5_DS and 6_DS the elaboration of the activity of the 3rd moment.

> "[...] So to work on the concept of quantity of matter (mol) I thought about preparing a sodium bicarbonate solution... I thought about bicarbonate because it's a product closer to them, that we use on a daily basis" (5_DS)

> "So I'm going to ask them in addition to interpreting the label, to convert it into another unit. I will then take the bicarbonate solution, beer, vinegar, hydrogen peroxide and alcohol. That's good, right?" (6_DS)

In this stage of content transformation, the student teacher again seeks examples of products from the students' daily lives to contextualize the activity, which occurs in the relationship between content and context (Shulman, 1986; Grossman, 1990). Furthermore, when she reflects on the organization of students into groups to carry out the activity, we see the mobilization of general pedagogical knowledge, which according to Shulman (1987) encompasses the general principles, strategies and skills related to teaching. This movement highlights the constitution of her PCK in the relationship between basic knowledge, content knowledge, knowledge of context and general pedagogical knowledge, as proposed by Gossman (1990).

Second Stage of The Analysis – After-Class Discussions

The analysis performed at this stage allowed us to interpret how the student teacher's Developed Pedagogical Content Knowledge (DPCK) occurred after teaching the EA and DS classes. This process gave rise to five

categories: Learning (L), Participation (P), Planning (PL), Teacher-Student Interaction (TSI) and Pedagogical Content Mediation (PCM). Next, we present the discussions regarding each and some examples of speeches, numbered in order of occurrence in discussions with the teacher educator, followed by the category code.

C1(DPCK) - Learning

In this category Jane presented insights about the students' abilities to understand the content during the lessons.

> "She said that this percentage was something of 100, but they didn't say mL, they said that this 0.9 g was something of 100". (1_L)

> "[...] in the discussions they are very good, but at the time of the calculations I now noticed that they do everything without units of measurement, like 80 to 1000, so they don't know what is being calculated". (2_L)

Lines 1_L and 2_L reveal the development of the student teacher's PCK through a process of verifying the students' understanding, one of the components of PCK according to the Shulman model (1986). It is, therefore, the construction of understandings about the actions of students in relation to the proposed activity and the didactic directions adopted by it, which also cause the construction of knowledge of the context, which according to Grossman (1990) is a sphere of teachers' knowledge that includes the knowledge of students. In lines 3_L and 4_L, we verified that she establishes a connection between her teaching purposes and the results of her teaching action, which indicates a process of evaluation and validation of the practice itself.

> "[...] they are very used to formulas, a student asked me: what is the formula I can use here?". (3_L)

> "[...] if they [students] leave, even with some doubts in calculations and conversions, but if they manage to interpret a label in daily life, it's already worth it. If they see 4% there [on the label] and understand that it is 4 grams in 100mL, it is already totally valid". (4_L)

It seems to us that the construction of new understandings about her practice occurs through the validation of her planning based on the results of her actions, which reveal evidence of an expansion of her PCK from the practical experiences lived out, as Shulman (1987) discusses the development of PCK through the transformation of basic knowledge and dialogue with the practice itself.

C2(DPCK) - Participation

This category refers to the involvement and participation of students while carrying out activities and conceptual elaborations during classes.

> "[...] they do very well. They discuss, expose the ideas even if it's wrong"; "And you saw that they

reached 250mL, didn't you?" (5_P)

In speech 5_P Jane highlighted the discussion about the volume of the serum bottles, which was one of the points she took into consideration during planning, portrayed in speech 2_DS during planning. In this case, we can identify a validation process of her planning, in which the student teacher evaluates and praises the students' participation when she mentions their attempt to solve the problem, as well as her own action, when she highlights the discussion about the volume of the serum bottle, making evident the perception about the importance of having prepared for such a situation, during the planning. We found that an environment favorable to participation contributes both to student learning and to the construction of teacher knowledge.
In lines 6_P, 7_P and 8_P we identified the construction of new understandings about the discipline, teaching strategies, students and the student teacher's own practice, which occured by her validating her planning and teaching purposes based on the results of her actions.

"I already knew it was a good group, but I didn't imagine they would provide arguments and participate like that. It's a new thing for them to solve problems, they don't do that and they are willing to discuss, find a solution [...]". (6_P)

"[...] today they were instigated yes, but there, handling the materials, doing the experiment, seeing what is happening, you know, I think they were more motivated". (7_P)

"So, to work using the approach allows them to interact, for them to become interested, to participate, the problematization draws attention, they get instigated, curious...". (8_P)

It is interesting to note that the student teacher builds understandings about the contributions of using a theme to address the content, having a problem to be solved to encourage student participation and the use of teaching strategies that bring the content closer to the reality of students, as in an activity of interpreting commercial product labels. This indicates that even if her PCK during the orientations was supported by specific knowledge, the general pedagogical knowledge and context, highlighted by Grossman (1990) in his model, contribute to the transformation of content into teachable knowledge, culminating in satisfactory results in terms of student learning and participation, as we have seen in the discussions so far. Therefore, we verified signs of an expansion of the PCK based on practical experiences, as Shulman (1987) discusses about the development of PCK through the transformation of basic knowledge and dialogue with practice itself.

C3(DPCK) - Planning

The construction of this category was based on Jane's considerations about the importance and need for a detailed planning of classes, both in relation to the content and the strategies that will be used, as well as the discussions that will be mediated to enable the construction of new knowledge by the students. It can be seen in speech 9_PL, the importance given by Jane to planning and preparing a script to guide her practice during classes.

> "[...] I prepare, I don't go to class without studying, I go with a script of what I'm going to do so I don't get lost". (9_PL)

This corroborates what was discussed during the analysis of the guidelines, in which we can observe that both in the preparation of the EA and the DS, she advocated the detailed construction of each moment of the classes, the examples that would be used to explain the content, the objectives, the learning intended by the students, the activities to be proposed, the teaching strategies, the organization of the class and the explanation of the content. This is validated by her when she reflects on the contributions of planning.

We understand that this importance given by Jane to planning is linked to her recognition of the contributions of the teaching methods used in classes, both in the EA and in the DS, evidenced in the lines 10_PL and 11_PL, in which she reflects on the management of content and activities based on the teaching methods employed.

> "[...] this division gives a direction, in the first moment I will do it like this, try to raise such ideas, then in the second moment I will discuss this, this and this and in the third I will apply..." This organization facilitates and helps a lot to conduct the class, because imagine, you take all that content and think: "Where do I start? Where will I end up?" (10_PL)

> "That's why it's important to teach an investigative experimentation class"; "[...] we work with experimentation to introduce the content..." (11_PL)

In speech 12_PL, her perception of student management is evident, something that had already been pointed out by Jane during planning, specifically in speech 6_DS.

> "[...] I asked each student to be responsible for an exercise, because then everyone is doing something..." (12_PL)

In this case, we see once again the evaluation and validation processes that the student teacher makes of her decisions and actions, which imply the development of her PCK through a dialogue with her own practice (Shulman, 1987).

C4(DPCK) – Teacher-student Interaction

This category concerns the contributions of the interaction between students and the student teacher and among the students themselves, both for carrying out the activities and for understanding the content, which in our understanding occurred due to Jane's attitude of trying to build an interactive dialogue with the class. In lines 13_TSI and 14_TSI there is a concept constructed by Jane about the need to explain the content to students.

> "[...] They need the teacher's explanation, and that's exactly the proposal of the three moments, isn't it?!"

(13_TSI)

"[...] They realize that I need their answers during class". "[...] in fact, it should always be like this, right, not only when we go there and do a different intervention, it should always be like this". (14_TSI)

We understand that this applies not only to the moment when she presented the concepts, but to every movement made during the class, in which she problematized the content, gave space for students to express their ideas, mediated the discussions, explained the concept of Solutions and gave them the opportunity to (re)build their previous ideas. Thus, we found that the development of her PCK is revealed here by the construction of the concept that the intellectual participation of students and the teacher's interventions in the explanation of the content must occur simultaneously during classes, leading to an interactive dialogue with a view to construction of new knowledge by students (Shulman, 1986).

C5(DPCK) – Pedagogical Content Mediation

This category encompasses both the student teacher's findings, as well as the discussions that took place during the orientations. We can see, in the statements 15_PCM, 16_PCM, 17_PCM and 18_PCM, the expansion of the student teacher's PCK clearly due to the validation of her practice, that is, the construction of new understandings about teaching.

[...] If I had gotten there and said that, the concentration in title is that, the concentration in the amount of matter is this... they would at most only use the formula, do some calculations, but they wouldn't be able to associate anything...". (15_PCM)

"[...] a problem related to a theme instigates them more, I think they get more involved because it's more related to everyday life". 16_PCM)

"Look, I think that in relation to their approach to everyday life, using a theme, working with the labels, makes all the difference...". (17_PCM)

"It was going to be memorization, right: "Oh I know there are three solutions, one is like this, the other is like this and the other is like that, but I don't know where this is present". But in this other way, even when they are going to prepare a juice they will know that they are preparing a solution [...]"; (18_PCM)

Such reflections by Jane, in our understanding, result in the construction of new understandings about teaching based on what was experienced in the classroom, which for us refers to the teacher's own practice and represents her findings about what was planned, developed and perceived about her teaching action, which since the beginning was driven by knowledge of the content and how to transform it into teachable knowledge (Shulman, 1986).

Discussion

Based on the analysis and the results presented, we elaborated Figures 3 and 4 that relate the categories and subcategories that emerged from Jane's reflections during the planning of the EA and DS classes and after they were taught. Next, we present Figure 3, elaborated by Arrigo (2021), which represents the development of the student teacher's PCK during the planning phase.

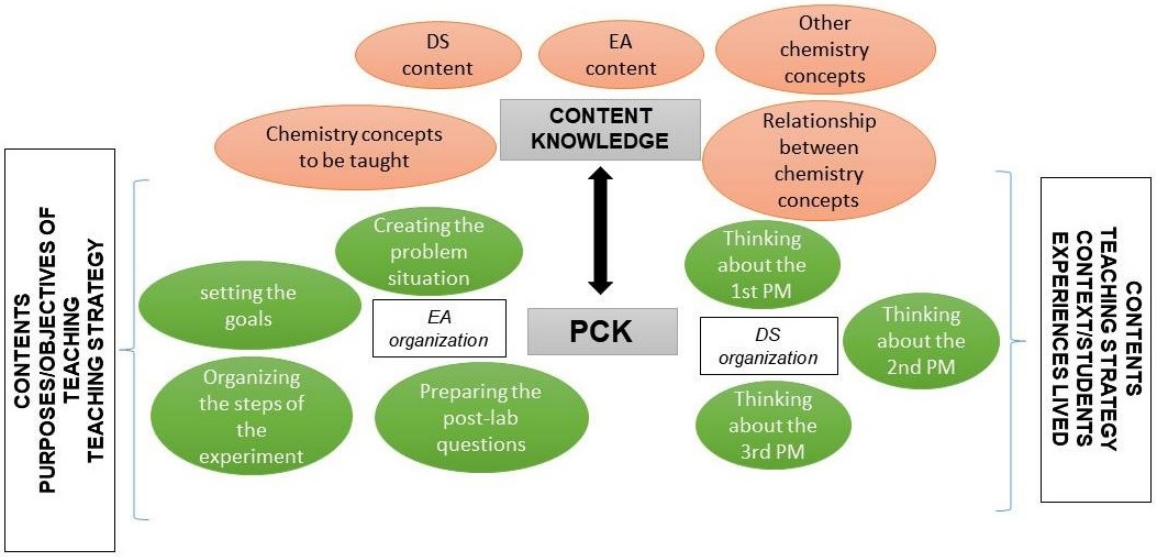


Figure 3. Categorization of Jane's speech during EA and DS planning

It is observed that, although the planning is based on content knowledge, the adopted teaching strategy exerted a strong influence on ther decision making, so that the unfolding of ideas occurred from the interrelationship between content knowledge and the teaching approach. Therefore, we understand that in this planning phase, Jane integrated specific knowledge into the teaching approach employed, while the mobilization of knowledge of the context, students, curriculum, subject, etc., happened as she was refining her intentions and teaching purposes. Unlike the preparation of the EA, in the preparation of the DS, the student teacher was more concerned with contextualizing the teaching and class management, which may have occurred due to the experience already lived in carrying out the EA or due to the characteristics of the teaching approach adopted.

These understandings seem to lead us to the integrative model proposed by Gess-Newsome (1999), in which PCK is not understood as a domain of knowledge, but as a construct originated from the intersection between general pedagogical knowledge, the theme (content) and the context. Although knowledge of the context and the general pedagogical aspects were not so evident in the student teacher's speeches during the preparation of the EA, we understand that they were part of the planning, even if implicitly, while they may have been more clearly revealed in the preparation for the DS because of the characteristics of the 3PM approach itself or because Jane had already performed the experimental activity, providing an initial contact with the students who made it possible for her to know some information about the characteristics of the class.

We understand, therefore, that Jane took the content of Solutions as a starting point, appropriated the principles

of investigative experimentation and the 3PM and established a context to support the explanation of the content. Therefore, even if knowledge of the context and general pedagogical knowledge were not as evident in her speech as content knowledge, we concluded that during planning, the student teacher's PCK was developed through the integration and not through the transformation of these three constructs, thus we identified similarities with the integrative rather than the transformative model (Gess-Newsome, 1999).

Next, in Figure 4, elaborated by Arrigo (2021), we can observe the development of Jane's PCK after teaching the classes, which occurred through a movement of her validating her own practice.

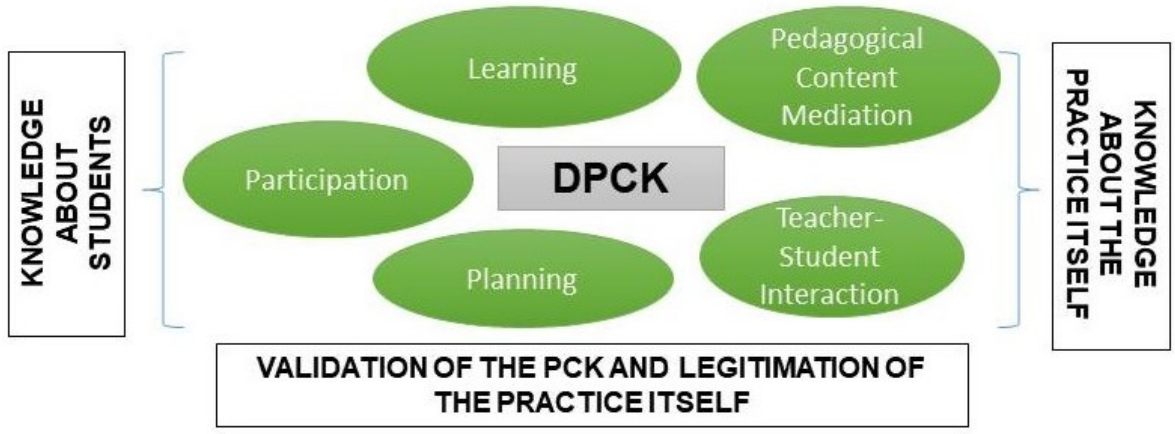


Figure 4. Categorization of Jane's speech after teaching the EA and DS classes

We verified that the student teacher's PCK was developed by a movement of validation of the practice itself, since the PCK identified in the planning phase was identified again, but accompanied by a reflective analysis of the results of her actions based on what occurred during the classes. Therefore, we defend that the development of Jane's PCK occurred in an intermediate way between the integrative and transformative models of Gess-Newsome (1999), because when she resumes the PCK mobilized in the guidelines, we see evidence of the integrative model, in which the basic knowledge does not change. However, when she assesses, reflects and builds new knowledge about teaching through the contrast between what she planned and what happened in the classroom, we find evidence of the transformative model, indicating that she built a new PCK, which will not return to be like the initial one, which also indicates the transformation of her base knowledge, which will not return to being as it was initially, since they were validated by the results of her teaching action.

Conclusion

In view of the research objective: to analyze the development of the PCK of a Chemistry student teacher in carrying out teaching activities in the Supervised Internship, we make some considerations. In the EA planning, we verified that the student teacher's PCK was mobilized as she reflected and planned the problem situation, the objectives, the steps of the experiment and the post-laboratory questions and validated such planning based on the initial reflections about the content and the teaching purposes, arising from the understanding phase. In the DS planning, we found that the student teacher's PCK was mobilized based on the relationship between content

knowledge, the characteristics of the 3PM approach and the experiences lived in the classroom in carrying out the experiment, which evidenced the mobilization of other knowledge from the base, such as general pedagogical knowledge and knowledge of the context, more evident in this stage of the analysis. At this stage, we understand that the mobilization of her PCK occurs through the integrative model, in which base knowledge does not change.

After the classes were taught, we realized that the development and expansion of the student teacher's PCK took place through a reflective process, which implied the validation of her own practice, leading to the construction of new knowledge about teaching and learning, students, content, teaching strategies, context, content management, class management and activities. In this case, we infer that this validation process legitimized the student teacher's practice, which implies, therefore, the expansion of her PCK and the improvement of her base knowledge, which becomes part of her knowledge base to be mobilized in future education situations, contributing to her professional teacher development. At this stage, we verified that the development of her PCK approached the transformative model, indicating that her PCK has expanded and will not go back to being as it was initially, which also implies the transformation of her base knowledge. In addition, we emphasize that the organizational structure of the Teacher Internship discipline, the interaction with the teacher educator, the teaching methods used and the class in which the activities were carried out, significantly contributed to Jane's professionalization in terms of development and expansion of her PCK, as it allowed her to mobilize her base knowledge and assess it after experiencing teaching situations based on the results of both her actions and the students. Therefore, we reiterate the notes made at the beginning of this article about the Supervised Internship, as a rich space for building knowledge for teaching.

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