ACTA SCIENTIAE

ISSN: 2178-7727
DOI: 10.17648/acta.scientiae.6627

Teaching Knowledge and Self-Concept: A Case Study Involving a Chemistry Teacher

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Received for publication 25 May 2021. Accepted after review 11 Nov. 2022
Designated editor: Renato P. dos Santos

ABSTRACT

Background: It is considered that, in order to teach, the teacher must have a base knowledge inherent to teaching and that the self-concept can influence the construction of this knowledge. **Objectives**: To analyse the correlation between teacher knowledge and self-concept. **Design**: This investigation began with a study on self-concept and teaching knowledge so it would be possible to build the theoretical framework that would support the collection and analysis of data. **Setting and Participants**: the participant of this research was a teacher who had been teaching chemistry for over 22 years in southern Brazil. **Data collection and analysis**: The body of data that constitutes this research permeates the analysis of semi-structured interviews, observations in pre-service teachers' diaries and teaching materials (such as biweekly plans, appraisals, among others). The analysis categories were the teaching knowledge model called the Hybrid Model and the self-concept categories: affective, cognitive and behavioural. **Results:** The components of teacher knowledge that most emerged were General Pedagogical Knowledge, Content Knowledge and Knowledge of Instructional Strategies for Science Teaching, while the most emerging self-concept categories were Behavioural and Cognitive. The categories that most occurred were General Pedagogical Knowledge with Behavioural Self-Concept. Thus, we understand that the way that this teacher interacts with his school space strongly influences the way he constructs his teaching practice. **Conclusions:** We infer that these connections can influence the construction of teaching knowledge of experienced and novice teachers. A better understanding of this process can help in understanding the teaching profession and, consequently, in predicting the efficiency and satisfaction of teaching practice, as well as pointing out possible ways to train chemistry teachers.

Keywords: Teaching knowledge, Self-concept, Chemistry teaching.

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Conhecimento docente e autoconceito: um estudo de caso envolvendo um professor de química

RESUMO

Contexto: Considera-se que para ensinar o professor deve ter uma base de conhecimentos inerentes à docência e que o autoconceito pode influenciar a construção desses conhecimentos. **Objetivos**: Analisar a correlação entre o conhecimento docente e o autoconceito. **Design**: Esta investigação iniciou-se com um estudo sobre autoconceito e conhecimento docente para que fosse possível construir o aporte teórico que sustentaria a coleta e análise de dados. **Ambiente e participantes**: o participante desta pesquisa foi um professor que lecionava química a mais de 22 anos na região sul do Brasil. **Coleta e análise de dados**: O corpo de dados que constitui essa pesquisa permeia a análise de entrevistas semiestruturada, diários de campo e matérias da docente (planos quinzenais, avaliações, entre outros). As categorias de análise foram a do modelo de conhecimento docente denominado Modelo Híbrido e pelas categorias de autoconceito: afetivo, cognitivo e comportamental. **Resultados**: Os componentes do conhecimento docente mais emergidos foram o Conhecimento Pedagógico Geral, Conhecimento do Tema e Conhecimento das Estratégias Instrucionais para o Ensino de Ciências, enquanto as categorias de autoconceito mais emergentes foram as de Comportamental e Cognitivo. As Categorias que mais coocorreram foram de Conhecimento Pedagógico Geral com Autoconceito Comportamental. Entende-se que a forma com que esta professora interage com seu espaço escolar influencia fortemente o modo que constrói sua prática docente. **Conclusões**: Infere-se que suas conexões podem influenciar na construção do conhecimento de professores experientes e novatos. O melhor entendimento desse processo poderá auxiliar na compreensão da profissão professor e, consequentemente, na predição da eficiência e satisfação do fazer docente, bem como apontar possíveis caminhos para a formação de professores de química.

Palavras-chave: conhecimento docente; autoconceito; Ensino de Química.

INTRODUCTION

Research carried out in recent decades on teacher education on assessment, methodology, teaching, among others, resulted in the consolidation of a research area that seeks to understand the knowledge inherent to the teaching profession (Almeida; Biajane, 2007; Chan; Hume, 2019; Slongo et al., 2010).

Lee Shulman (1986, 1987) was one of the researchers dedicated to unveiling teachers' knowledge. In Shulman's perspective, "to call something a profession is to assume that there is a knowledge base largely built in the academy" (Shulman, 2004, p.13).

Research on teaching knowledge highlights that mastery of specific content alone is not enough to teach, as people understand that there is a set of knowledge that would characterise teaching, among which Pedagogical Content Knowledge (PCK) stands out, which encompasses "the most regularly taught topics in your area of study, the most useful ways of representing those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations" (Shulman, 1986, p.9). The PCK is believed to represent the integration of knowledge that the teacher needs to teach content (Rollnick et al., 2008).

Grossman (1990), one of Shulman's collaborator, reorganised the seven knowledges of the teacher knowledge base proposed by her advisor in the model of relationship among the domains of teacher knowledge (Fernandez, 2015), structured by four components: 1) General Pedagogical Knowledge; 2) Subject Matter Knowledge; 3) Pedagogical Content Knowledge, and 4) Knowledge of Context. In Grossman's (1990) proposal, the PCK is one of the components of the teaching knowledge base, but specific models for the PCK are described in the specialised literature (Goes; Fernandez, 2018).

In studies carried out by Freire and Fernandez (2014), the researchers consider that the knowledge of the base model does not depend on specific content or area of teacher education to emerge. However, the PCK is related to a specific content of a subject matter.

In the literature, several researchers have proposed models to define the PCK, as reported in some state-of-the-art research (Goes; Fernandez, 2018); thus, Park and Oliver (2008a, 200b) consider that the PCK is constituted by the following components: Guidelines to Teaching Science, Knowledge of Curriculum, Knowledge of Students' Understanding of Science, Knowledge of Instructional Strategies to Science Teaching, and Knowledge of Assessment of Student's Learning of Science.

To some researchers, teachers need developed teaching knowledge and motivational guidelines to teach effectively (Baumert & Kunter, 2013; Blömeke, Gustaffson, & Shavelson, 2015). For Möller et al. (2011) teaching knowledge and motivational orientations influence each other. Therefore, researchers suggest the development of studies that analyse the influence between self-concept on teacher knowledge and vice-versa, as they are scarce in the literature (Paulick et al., 2017).

Self-concept – some considerations

The notion of self-concept was first analysed in greater depth by psychologist William James in his book entitled Principles of Psychology. In James' perception, the self-concept would represent everything that the subject can call his/her own.

After the initial studies on self-concept, other authors focused on understanding its connection with family relationships, academic performance, among others. They also sought to associate self-concept with the success that the subject seeks in actions that he/she considers important.

Moreover, although self-concept permeates several studies, there is no consensus on its definition (Serra, 1988), reflecting on conceptual confusions with self-image and self-esteem, as a result of their influences on the formation of the "individuals' ego, self and personal and social identity" (Novaes, 1985, p.28). In this perspective, Sánchez and Escribano (1999, p. 13) consider that "self-concept is an evaluative attitude that an individual has about him/herself, about his/her own person. It is about the esteem, feelings, experiences, and attitudes that the individual develops about his/her own self".

The concept of self-concept described by Shavelson et al. (1976) can be presented as a person's awareness of him/herself, i.e., how this person perceives him/herself in a given scope/domain. This self-awareness is described as multifaceted, hierarchical, and stable, constructed through experiences, interpretations of one's environment, and which is especially influenced by assessments of other reinforcers and attributions of one's own behaviour (Shavelson & Bolus, 1982; Marsh et al., 1984; Marsh & Shavelson, 1985).

An interpretation model described by Shavelson et al. (1976) proposes that within a general self-image, not only the academic self-concept, of content, but also the social, emotional, and physical self-image would be present, i.e., a fragmented spectrum in different areas of the self-image, revealing itself in multifaceted unfoldings (Shavelson & Bolus, 1982).

In general, the multifaceted feature of self-concept is practically a consensus in the literature. However, there is disagreement among researchers as to how the unfoldings of self-concept (academic self-concept, non-academic self-concept, and others) organise and interact with each other, within a single model of theoretical representation (Marsh & Shavelson, 1985). The multifaceted feature of self-concept means that there are specific perceptions

for specific fields, such as students' academic self-concept for different subject matters such as, for example, Portuguese, science, mathematics, among others.

For some researchers, the self-concept would represent the understanding that a person has about him/herself, a reflection of the interactions between him/her and his social environment (Zacharias, 2012) and, consequently, how a person recognises him/herself, understands his/her attitudes, potentialities, among others.

Other researchers do not distinguish self-concept, for example, from self-esteem. In this sense, Marsh (1993, p. 67-68) describes: "I do not distinguish self-concept from self-esteem in my investigation, although I strongly emphasise the difference between global components and components related to specific domains of self-concept (or self-esteem)". However, in this research, we understand that self-concept is a concept that permeates self-image and self-esteem, but that can also be understood as a component of cognitive assessment. In this perspective, we adopted Peixoto's definition: "using the designation self-concept whenever we refer to representations related to specific domains of competence and/or their sum (i.e. global self-concept)" (Peixoto, 2003, p.14).

There are several studies on the formation of students' self-concept, and there are few that have sought to reveal the teachers' self-concept, which is a challenge for research in education (Paulick et al., 2017), given that the knowledge of self-concept is one of the best predictors of analysing the performance and satisfaction of teaching work (Judge & Bono, 2001). Furthermore, Tamayo (1985, p. 89) states that "[...] the interaction and the social roles constitute the context in which the exchange of feelings and looks takes place and in which the perceptions and expectations that emerge progressively structure the self-concept". Another study points to the prospective teachers' self-concept about their professional knowledge, more specifically, content knowledge (CK) and PCK (Paulick et al., 2016).

Some studies adopt models to relate teacher knowledge and self-concept. In this sense, the GI/E model (generalised internal/external frame of reference model) is a well-established theoretical framework that proposes to understand academic self-image, organise and make predictions of the relationships between professional knowledge (CK and PCK), self-image and interest (Paulick et al., 2017; Sorge et al., 2019).

Sorge et al. (2019) proposed some hypotheses about the interactions between teacher knowledge and self-concept. The hypotheses suggest that CK

and PCK positively affect their respective self-images and interests at the same time that affect their non-corresponding self-images and interests negatively.

Sorge et al. (2019) propose important parameters to think about how the teaching knowledge of experienced teachers influences and is influenced by these professionals' self-concept.

Considering the above, this research aimed to investigate the possible mutual influence between teaching knowledge and the self-concept of an experienced chemistry teacher.

METHODOLOGY

This research appears as qualitative, which we characterise as involving a natural environment in which the data are mostly descriptive, has an inductive direction for data analysis, among others (Bogdan & Biklen, 2003). In this investigation, the qualitative research is of the case-study type, as it was carried out in a particular context in which we sought to understand a problem (Yin, 2010). We understand that the case study aims to portray and interpret a real context thoroughly. Therefore, we adopt a variety of data sources to make it possible to represent the different perspectives on a given social situation (Lüdke & André, 2013).

This case study is considered unique, as it sought to portray a particular context of a chemistry teacher who teaches in basic education, in which we inferred that he feels that he masters the contents of chemistry to teach and, consequently, has a good self-concept as a teacher. This situation adds to the relevance of this teacher in the school institution where he works, due to the extracurricular activities that he organises and implements in the school, to the students' respect towards him, among others. Thus, we suggest that the possible self-concept of the teacher participating in this research may be strongly related to his teaching knowledge and vice versa.

In line with the above, this research was developed by triangulating the data collected, namely: i) a semi-structured interview, recorded in audio and later transcribed, which raised questions about the professional trajectory of the participant in this research and questions related to their self-concept and his teaching knowledge; ii) document analysis of the biweekly plans, didactic materials produced, assessments, class presentations, assignments, and exercise lists; and iii) analysis of the field diaries of five undergraduates who had the participant in this research as a supervisor during their supervised teaching practices. The field diary is a material required by the Supervised Teaching

Practice supervisor, which seeks to detail the observations made by the undergraduates in the classroom and bring reflections of these subjects on the teaching practice of their supervisor. It is important to mention that fictitious names were given to the licentiates and to the research subject, and that this research was approved by the ethics committee for research involving human beings.

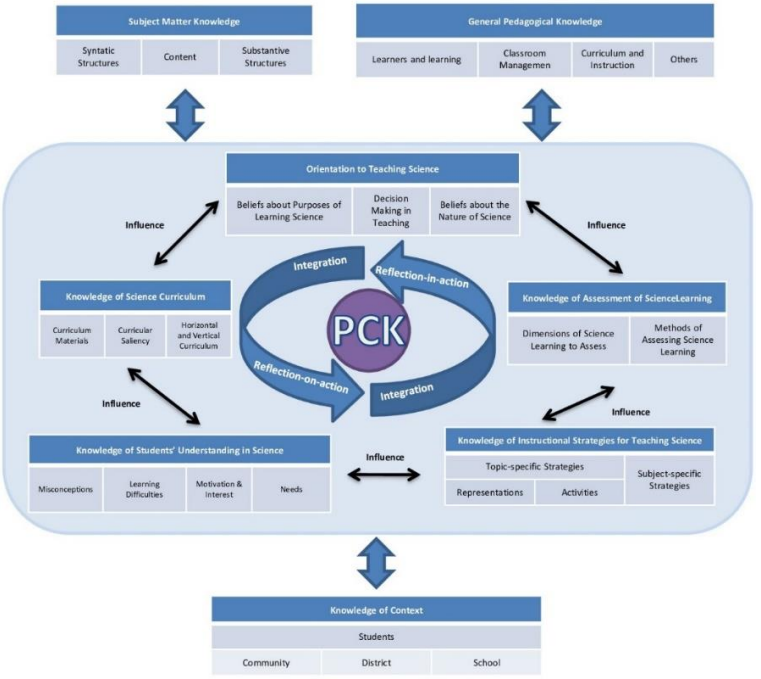
Categories of analysis

To analyse the possible correlation between teaching knowledge and self-concept, we adopted a priori categories, defined from the literature. In this sense, for the analysis of teaching knowledge, we adopted the components of the base model for teaching proposed by Grossman (1990), except the PCK, together with the categories of the PCK by Park and Oliver (2008a, 2008b), namely: *Subject Matter Knowledge*; *General Pedagogical Knowledge*; *Knowledge of the Context*; *Guidelines for Science Teaching*; *Knowledge of the Science Curriculum*; *Knowledge of Science Learning Assessment*; *Knowledge of Students' Understanding of Science*; *Knowledge of Instructional Strategies for Science Teaching* (Nogueira, 2018; Park & Oliver, 2008a, 2008b). Figure 1 presents the analysis categories that constitute the hybrid model.

In this hybrid model, Nogueira (2018) understands that the teacher knowledge base, including the PCK as one of its components, perhaps reveals itself mainly in the teachers' professional practice.

Figure 1

Hybrid model. (Adapted from Nogueira (2018))



For the analysis of self-concept, the categories were defined as: i. *affective self-concept* - represents self-image, involving emotional aspects, i.e., it rests on the expression of emotions; ii. *cognitive self-concept* - contemplates the cognitive skills and perceptions that the subjects notice about their mastery of knowledge for teaching and; iii. *behavioural self-concept* - portrays how the subject relates to the environment in which he/she lives (Sánchez & Escribano, 1999).

***Software* Atlas.ti**

In this research, the ATLAS.ti software was adopted in the data analysis process (Klüber, 2014). ATLAS.ti allows you to relate documents such as videos, audios, and texts with the categories determined by the researcher and their main elements in the adopted version, namely: Hermeneutic Unit, Primary

Documents, Quotes/Quotation (statements), Codes/Coding (categories), Memos (analysis notes) and Network View (graphic schemes) (Klüber, 2014).

We created a hermeneutic unit for each of the primary documents - interview, students' field diaries of the Supervised Teaching Practice I, II or III, and/or materials from a high school series the teacher made available-, which were added to the units and automatically enumerated by the software. Then, we created codes (categories) to classify the quotes (statements). For the interviews and field diaries, we decided to attribute a code to each paragraph. For the materials provided by the teacher, we decided to give a single code and categorise the document as a whole.

RESULTS AND DISCUSSION

The participant in this research, Adele, graduated with a degree in chemistry and has been teaching for over 22 years, having worked at the same school for 11 years, where she teaches 40 hours a week. Currently, in the context of the pandemic, she has been doing postgraduate studies in chemistry teaching methodology.

The analysis of the collected data allowed the emergence of co-occurrences of Adele's Self-concept categories and Teacher Knowledge. Accordingly, the results of the analysis of the teacher's knowledge and self-concept in the documents described in the methodology generated in Atlas.ti were grouped in Figure 2.

In total, 1708 categories emerged in all documents analysed. The *General Pedagogical Knowledge* was the most present in Adele's teaching knowledge, with 508 excerpts categorised in this component of base knowledge, followed by the *Behavioural* category, with 288 occurrences.

It is noteworthy that although the objectives of this research are to analyse the possible self-influence between teacher knowledge and self-concept, discussions will be held about the influences between the components of Adele's knowledge base due to their inseparability emerged in part of the analysed data. Therefore, Figure 3 brings the co-occurrences between the components of teaching knowledge generated by the Atlas.ti software.

Figure 2

Report generated on Atlas.ti – Adele's Self-concept and Teacher Knowledge

Document	Self-concept and Knowledge base categories											Total
	α	β	γ	A	B	C	1	2	3	4	5	
Interview with Adele – Part 1	7	11	16	2	17	2	0	0	0	0	0	55
Interview with Adele – Part 2	11	29	22	34	46	12	1	13	3	14	5	245
Diaries of Ivan Stage I	4	0	13	15	46	0	5	4	7	13	3	110
Diaries of Ivan Stage II	7	2	30	41	49	1	3	18	8	32	4	195
Diaries of Erica Stage II	5	4	50	28	93	13	9	17	11	52	27	309
Diaries of André Stage I	1	0	3	6	8	0	1	2	0	8	0	29
Diaries of André Stage II	0	0	27	14	34	3	0	9	1	21	5	114
Diaries of André Stage III	3	1	28	11	33	9	3	4	3	16	3	114
Diaries of Linda Stage I	0	0	4	17	44	4	1	9	5	21	3	108
Diaries of Linda Stage II	1	2	18	14	41	1	2	13	1	6	2	101
Diaries of Linda Stage III	2	5	31	16	30	1	3	2	8	8	5	111
Diaries of Renan Stage III	4	0	46	11	51	2	1	0	3	6	2	126
Materials provided by Adele for the 1st year Secondary school	0	0	0	3	3	2	2	3	2	3	1	19
Materials provided by Adele for the 2st year Secondary school	0	0	0	6	3	2	3	5	1	4	1	25
Materials provided by Adele for the 3st year Secondary school	0	0	0	5	5	3	1	2	1	4	2	23
Materials found in pre-service teachers diaries	0	1	0	5	5	0	2	5	0	1	5	24
Total	45	55	288	228	508	55	37	106	54	209	68	1708

α – Affective, β – Cognitive, γ- Behavioural, A – Subject Matter Knowledge, B - General Pedagogical Knowledge, C - Knowledge of the Context, 1- Guidelines for Science Teaching, 2 - Knowledge of the Curriculum, 3 - Knowledge of Students' Understanding in Science, 4 - Knowledge of Instructional Strategies for Teaching Science and 5 - Knowledge of Assessment of Learning in Science.

Figure 3

Report generated in Atlas.ti – Co-occurrence between Adele's teacher knowledge categories

Category	5	3	4	C	2	A	B	1
5	0	3	44	4	14	20	27	3
3		0	18	3	13	27	26	5
4			0	13	57	129	125	15
C				0	9	10	36	5
2					0	78	64	17
A						0	123	23
B							0	22
1								0

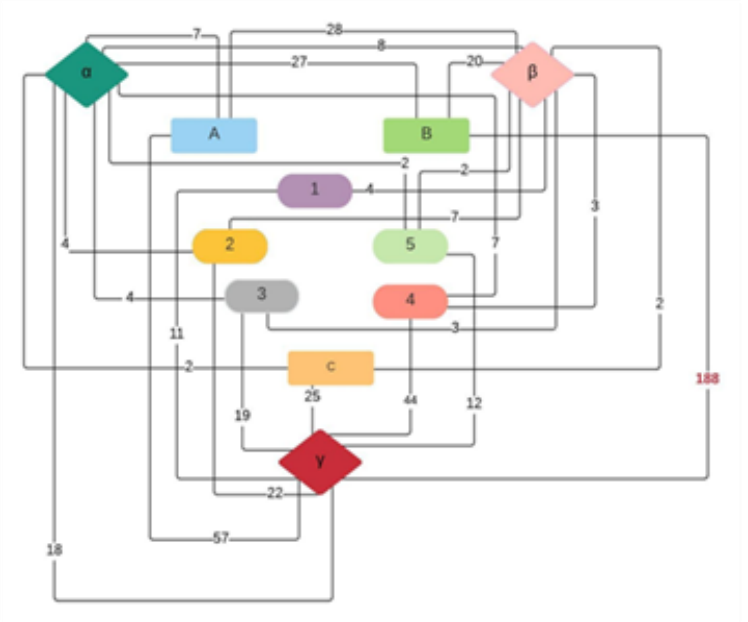
α – Affective, β – Cognitive, γ- Behavioural, A – Subject Matter Knowledge, B - General Pedagogical Knowledge, C - Knowledge of the Context, 1- Guidelines for Science Teaching, 2 - Knowledge of the Curriculum, 3 - Knowledge of Students' Understanding in Science, 4 - Knowledge of Instructional Strategies for Teaching Science and 5 - Knowledge of Assessment of Learning in Science.

According to data in Figure 3, the highest co-occurrence (129) was among the components: *Knowledge of Instructional Strategies for Science Teaching* and the *Subject Matter Knowledge*, followed by the mutual influence between the *General Pedagogical Knowledge* and *the Instructional Strategy for Science Teaching*. It is noteworthy that Adele's general pedagogical knowledge strongly influenced her teaching, regardless of the chemistry content covered in her class.

The third self-influence among the knowledge base components was between the *Subject Matter Knowledge* and the *General Pedagogical Knowledge*.

Figure 4

Co-occurrences between Adele's Self-concept and Teacher Knowledge categories.



α – Affective, β – Cognitive, γ- Behavioural, A - Subject Matter Knowledge, B - General Pedagogical Knowledge, C - Knowledge of the Context, 1- Guidelines for Science Teaching, 2 - Knowledge of the Curriculum, 3 - Knowledge of Students' Understanding in Science, 4 - Knowledge of Instructional Strategies for Teaching Science and 5 - Knowledge of Assessment of Learning in Science.

As the objective of this research was to investigate the possible mutual influence between teacher knowledge and self-concept and vice versa, Figure 4 shows the co-occurrences between Adele's these categories. Each geometric shape represents a category, specified by number or letter. The lines that interconnect the forms represent a co-occurrence between the categories in question. The number on the line indicates how many times the two categories co-occurred in a given excerpt or document.

According to the data in Figure 4, Adele's most emerging self-concept was the *Behavioural* (Figure 2). Furthermore, the categories *General Pedagogical Knowledge* and *Behavioural Self-concept* are significantly related to each other, with 188 co-occurrences. This mutual influence of these components of base knowledge and Adele's self-concept may be a reflection of how the teacher interacts (behavioural self-concept) with the school community in which she works, participating in projects such as, for example, the monitored recess, the school councils class, and always looking to connect with the students in their classes. It is also possible to see that the self-influence of the *General Pedagogical Knowledge* and the *Behavioural Self-concept* are more strongly connected, as the *General Pedagogical Knowledge* was the most present in the knowledge base for Adele's teaching. This category represents the way in which the teacher adopts her pedagogical strategies, organises classroom management, her knowledge of the curriculum, and instruction in order to achieve the objectives related to her students' learning. It is knowledge that transcends the limits of a specific discipline.

In this sense, this knowledge strongly influences the way Adele teaches her classes, as, regardless of the content, they generally follow the same path: exposure to the content occurs through a slide presentation that the teacher prepares. In those lectures, the teacher brings to the discussion elements of the history of science and its processes, and often uses examples and analogies that relate chemical content to apparently unrelated aspects of everyday life. Then, after teaching all the content, the teacher solves part of the list of exercises on the subject (previously presented on the school portal) or makes part of the class time open for discussing students' doubts.

Content assessment occasionally occurs through group work, but the most used form is a written assessment in the classroom. The teacher conducts one experiment per semester and asks her students to submit a scientific report on the activity, which will also count as one of the grades for the semester. Often, the teacher also holds competitions as teaching strategies. The teacher

also uses the result of the competitions as an assessment, which becomes one of the grades of the bimester in which it was applied.

Adele usually maintains her class schedule, which has undergone few changes over the years she has taught, as the following excerpt shows:

> It's the sequence, and it's a routine, it's a routine year after year, and you know that's how you're going to teach your classes. So it can even seem like "hey, but she never changes the sequence, she never changes, I am, at this point, I am very square, because I think that chemistry links its contents, so, sometimes I see, I even I made a complaint to a publisher about this, they brought the contents totally out of, of a specific logic, of a sequence, of a logical construction of knowledge, so they talked about the periodic table before talking about atomic structure, so, how can you talk about chemical elements if you don't know what an atom is, and you don't know the difference between an element and an atom and you don't know what an electron and a proton are, how are you going to make an electronic distribution to understand the sequences on the table, you know? So, at this point, I'm pretty traditional. (Semi-structured interview part 2, shift 81)

Adele's *General Pedagogical Knowledge* influences the components of her PCK, more specifically, the way she teaches specific content. Therefore, one of the strategies most adopted by Adele is the resolution of questions from lists of exercises in the classroom, together with the students – *Knowledge of Instructional Strategies for Science Teaching.* These questions are usually the ones found in entrance exams because, for Adele,

> those lists of exercises are pulled from college entrance examination questions, ENEM questions. Because I'm... I'm stuck with it. As much as my class is dynamic, it is geared towards my daily life, right? So that the student can understand the importance of chemistry. Uh... they have a college entrance exam ahead of them to pass. (Semi-structured interview part 2, shift 157)

In the shift mentioned above, Adele believes that it is important that her lists of exercises are per the contents found in the entrance exams. Adele affirms other moments in which she uses the summary of textbooks to form the basis

of the curriculum that the Ministry of Education (MEC) elaborates – *Knowledge of the Curriculum*.

To teach his students, he chooses, as a way to mediate this process, competitions that consist of activities in which the class is divided into three groups: team 1, team 2, and "undergraduates", who help the two teams if so requested, and the teacher, who reads the questions to be answered by the teams. The competition is also used as an assessment and makes up one of the grades for the bimester. This strategy is often reported in the undergraduates' diaries, and they all occurred in the same way in the different high school classes and regardless of the chemical content taught - *Knowledge of Instructional Strategies for Science Teaching* and *Knowledge of Science Learning Assessment*.

Although the competition is a relaxed activity and interaction between groups and the teacher (behavioural self-concept), it ends up following the molds of a traditional assessment, as the undergraduate Erica describes in her diary: "[...] I was a little disappointed to realise that the competition takes place as a common test, but in groups, orally, and with little time available for solving each question, which follows the pattern of test questions" (Erica's field diary).

Adele's way of organising materials and content she will teach suggests that the teacher knows the curriculum and that she implements it with a focus on teaching for the college entrance examination.

Like the competitions, the questions selected by the teacher to apply in her assessments generally follow a multiple-choice pattern, based on college entrance exams. It is evident in all the documents analysed that traditional tests are the main forms of assessment used by the teacher, but that despite this, Adele uses other assessment forms, such as works, reports of experiments, and competitions, denoting a knowledge about the component methods of learning assessment in science, referring to the *Knowledge of Learning Assessment in Science*. About the assessments, Erica says that "[...] We cannot forget that in her education, she probably did not have the opportunity to study other forms of assessment, so maybe she works mostly with tests, because she doesn't know the potential of other styles of assessment" (Erica's field diary). The *Knowledge of Instructional Strategies for Science Teaching* and *Knowledge of Learning Assessment in Science* are strongly influenced by Adele's *General Pedagogical Knowledge*.

About her education, the teacher says that most of the subject matters for teaching were taught by non-specialist professors in chemistry teaching,

which probably limited her contact with differentiated and specific methodologies for that activity. During her entire graduation, she had contact with only one professor who was an expert in chemistry teaching. Regarding the classes focused on the undergraduate part, Adele reports that:

> Look, it was really frustrating. Quite frustrating in the sense that it was very theoretical. Many philosophers, many... how can I tell you... many thinkers related to education, but you had the impression that they were from another decade, another century, because that was not what you had in the classroom. (Semi-structured interview part 1, shift 105)

In this sense, we must also take into account the teacher's trajectory, as Erica reported, because, besides problems related to her education, she has a workload of 40 hours per week, which can cause an overload of work and lack of motivation in the search for additional formation.

The *General Pedagogical Knowledge* (curriculum and instruction) influences Adele in constructing her teaching materials and how she uses them in her classes.

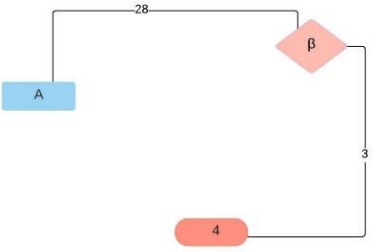
It is noteworthy that all the teacher's classes are taught with slide presentations, which, according to Adele, serve as a guide for her speech and not necessarily as a material for the students. In the context of the pandemic, the teacher reported that she adapted her slides, adding content in text so that students do not need to take so many notes during classes – *Knowledge of the Context*. Her rigid schedule reflects how the professor chooses to organise her subjects, based on her *General Pedagogical Knowledge* component (students and learning).

The category *Subject Matter Knowledge* deals with Adele's specific knowledge of a chemistry content. In this research, we consider that this knowledge is one of the most difficult to access, but, from the documents analysed, it was possible to make inferences based on theoretical support about some chemistry contents. The field diaries evidenced how the professor has a rich repertoire of examples and analogies for the content of organic chemistry, which can demonstrate her knowledge on this subject - *Instructional Strategies for Science Teaching* and *Subject Matter Knowledge*. During the classes on nitrogen functions, Adele discusses with students the presence of nitrogen in hormones and drugs, how these substances act in our bodies, problematising the addiction that psychoactive substances cause. In a class on the same subject, the professor presents the history of explosives, talking about nitro-glycerine

and TNT (trinitrotoluene), but shows the wrong molecular structure of nitroglycerine. It is noteworthy that Adele has a good *Cognitive Self-concept* for this topic, which perhaps reflects on how it is taught – *Instructional Strategy for Science Teaching*, as suggested by the co-occurrence of those categories of analysis, shown in Figure 5.

Figure 5

Co-occurrences of Cognitive Self-concept with Adele's Subject Matter *Knowledge and Knowledge of Instructional Strategies for Science Teaching*



β – Cognitive, A – Subject Matter Knowledge, and 4 - Knowledge of Instructional Strategies for Science Teaching.

Regarding the content she most likes to teach, Adele says that:

> I like physical chemistry, because it can interact with everyday life. It is there in my everyday life. Yeah... I talk about medicines, I talk about food, I talk about... I can teach without mentioning a single chemical compound. You know? [...] Why can I take [a drug] only every six hours? So, I'm there... solutions, I talking about sugar in coffee. There are three spoons. The third damn spoon doesn't dissolve. It's no use putting it there because it is no use for your coffee. You know? You're wasting sugar. So, I think that at this point, physical chemistry, it is very... very interesting. Ok? It... it can make the link. Show the importance of chemistry. After that, organic, right? (Semi-structured interview part 2, shift 237)

The shift above suggests that the professor prefers to teach classes on topics related to physical chemistry, such as kinetics and solutions (cognitive self-concept, as she believes that it is simpler to establish comparisons with her

students' daily lives. The second topic she likes to teach most is organic chemistry. It is possible to suggest, through Adele's reflection present in this excerpt, that the professor has a good *Cognitive Self-concept* about her *Subject Matter Knowledge* on physical chemistry and organic chemistry, which, consequently, influences the way she teaches those subjects.

About Adele's *Subject Matter Knowledge*, a problem identified in her materials was the misrepresentation in chemical reactions and not considering the angles of organic compounds in other representations, which can impact student learning. Other conceptual mistakes emerged in Adele's classes, as Ivan's record in his field diary shows: "Among all the explanations given around nitriles, that of the holocaust was given again, and the class paid attention. However, again the teacher made the mistake of saying that nitrile reacts with oxygen" (Ivan's Teaching Practice II field diary).

Despite some conceptual mistakes present in Adele's classes, it is evident that the teacher has knowledge in different ways of approaching a topic of organic chemistry - *Knowledge of Instructional Strategies for Science Teaching*, which suggests that the teacher had a good *Cognitive Self-concept* to teach this topic - organic chemistry.

However, in the slides of the thermochemistry class, Adele confuses the concepts of heat and temperature in several places. Sometimes the professor uses phrases like "the heat passes" or "it takes off heat", attributing the character of substance to an abstract concept. The heat process is actually one of the forms of enthalpy change. It is common for professors to relate heat to the zero law of thermodynamics, where thermal equilibrium occurs with the contact of two bodies (McQuarrie & Simon, 1999).

When asked about the subject of chemistry that she least likes to teach, the professor replies that she had difficulties with electrochemistry in her undergraduate course, and that this is the content she least wants to teach:

> I don't teach electrochemistry. I don't know if you've noticed? I give it in the form of work. First, because I don't have time. I don't have time. Because electrochemistry comes in the last quarter. It has to do with chemical balance. It has to do with kinetics. [...] So I end up focusing on electrochemistry as uh... a work. But that doesn't mean I don't work on it. (Semi-structured interview part 2, shifts 247 and 249)

The excerpt above suggests that Adele has a low *Cognitive Self-concept* for electrochemistry, which influences their choices about how to teach and

assess this topic (knowledge of instructional strategies and knowledge of science learning assessment). The literature says that the contents that involve electrochemistry are one of the most difficult to teach in chemistry, leading teachers not to teach this content (Goes, Nogueira, & Fernandez, 2020). Accordingly, Adele describes the way she teaches the subject of electrochemistry (Knowledge of Instructional Strategies and Knowledge of Science Learning Assessment):

> They search. Later, they are questioned about that. They answer it, and can consult the summary they made. So I open it. I do experiments on electrochemistry, right? So, there's a report. So, they will do a lot of research. They will read a lot about it. For sure. The only part I don't work on is the oxide reduction reactions of electrochemistry. (Semi-structured interview part 2, shift 253)

In her field diaries, undergraduate Erica registered how Adele taught the topic of electrochemistry, describing that:

> I don't know very well the professor's relationship with this content, but I suppose she is not very familiar with it, since she could have chosen any other topic not to address it, but she preferred this one. Although we will not talk about "Electrochemistry", two activities are to be carried out on the subject, which took place today: a questionnaire and an experiment.

Behavioural Self-concept was the most frequent self-concept category in the analysed documents, especially in the field diaries, and the second category that most emerged. This category shows how the individual relates to his/her environment. The documents brought many examples of how the professor behaves in her work environment and during her classes. Adele has been teaching since 2010 at the same school, and, during that time, she had the opportunity to play important roles in this environment, such as in the school's deliberative council, which oversees actions by the school management, directing funds received, and acting as an ombudsman for the school community. About this experience, Adele reports that:

> It's interesting, you live together, you realise the amount of problems you have in a school when you are part of the council. I was part of it for four years and look, I had to go to the police station to file a complaint. [...] It's very complicated. Nobody

> likes to participate in the deliberative council. Because all the problems come to us. (Semi-structured interview part 2, shifts 93 and 97)

Besides having participated in an administrative part of the school, over time the teacher performed other functions and projects. It is noteworthy that, for years, Adele has been developing the project called *Recreio Monitorado* (monitored break time). Although this project was developed together with other teachers, Adele was the one who conceived it and spent the most time coordinating it. The project consists of using the school gymnasium during class breaks as a recreational space for students from the first to fourth grades of the first years of elementary school (6-10 years of age). These students participate in activities organised by volunteer high school students. This project suggests that Adele's *Knowledge of the Context* is influenced and influences her *Behavioural Self-concept* by proposing actions that meet the demands of the school in which she works and by directing students towards activities that develop responsibility and collectivity.

Undergraduate Linda reports in her Teaching Practice I field diary that the teacher does not currently carry out interdisciplinary projects with other teachers because of negative experiences, in which the other teachers involved did not collaborate effectively in elaborating and applying the projects, making them incomplete, and making the work unfeasible.

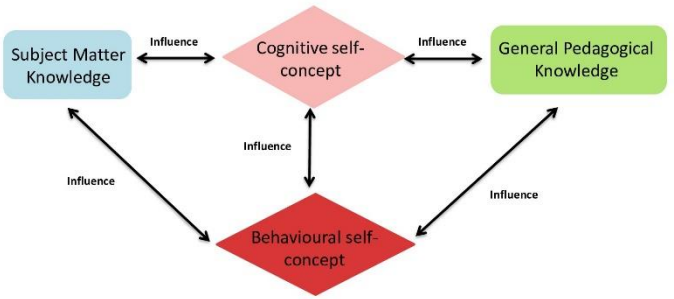
In the classroom, the teacher usually does not tolerate jokes when she is explaining the concepts - *General Pedagogical Knowledge and Behavioural Self-concept*. These two categories of analysis present a 188 times co-occurrence, in addition to other student behaviours that may interfere with class organisation. The teacher also does not allow external interruptions to her classes, even if they are messages from the direction. On the other hand, she often maintains friendly and affectionate relationships with her students (general pedagogical knowledge and affective self-concept), which influences how she mediates students' teaching-learning. In his Teaching Practice III field diary, André reports that during the Easter period, Adele was dressed up for her classes: "The teacher was also dressed up – she had rabbit ears, her face painted with moustaches and nose and a rabbit tail stuck to her pants. The students thought her characterisation was great, and I heard comments like "Teacher, we cant' take you seriously" (André's Internship III field diaries). Those situations show how Adele's *Behavioural Self-concept* influences her *Affective Self-concept* and vice versa.

Undergraduate Linda reported in her field diaries that Adele sometimes changed the lesson plan of the students who performed the mandatory teaching practice in her classes and interrupted classes implemented by the undergraduates in chemistry. This behaviour was not only observed in Linda's field diaries, other undergraduates reported similar situations. Adele's actions denote negative behaviour towards her prospective teachers in training - *Behavioural Self-concept*. The teacher's interruptions may be related to her *Cognitive Self-concept* for teaching. In this sense, we infer that Adele considers that she has a repertoire for teaching (cognitive self-concept). Moreover, she feels free to change the planning and interrupt classes and even explain again, during the conducting, concepts taught by undergraduates (knowledge of the subject and cognitive self-concept)

In this way, her *Cognitive* and *Behavioural Self-concept* influence each other. Along with this situation, Adele's *Cognitive Self-concept* impacts her *General Pedagogical Knowledge* and her *Subject Matter Knowledge*.

Figure 6

The mutual influence between teaching knowledge, cognitive self-concept and Adele's behavioural self-concept



We also suggest that Adele's actions towards the undergraduates may result from her insecurity with her repertoire of teaching strategies, as the undergraduates present a different repertoire to teach chemistry, with approaches that Adele may not adopt in her classes. This insecurity can also result in the behaviour described above. Figure 6 presents the schematisation

of the mutual influence between Self-concept and teacher knowledge on Adele's behaviour. So, what influences Adele in her choice for teaching.

Guidelines for Science Teaching deal with the professor's beliefs about the proposals and objectives of teaching science and the teacher's beliefs about the nature of science. This category emerged the least in the documents analysed and aspects of this teaching knowledge emerged in the materials made available by her, especially her biweekly plans:

> Chemistry is essential in our quality of life. It is all around us. She brings solutions from construction to the comfort of home, for leisure or games, from means of transport to the means of communication, from technology to clothing, from agribusiness to pharmaceuticals, among hundreds of other applications. In short, chemistry is inseparable from all aspects of our lives. (Materials provided by Adele for the 3rd year - biweekly plan)

The excerpt above brings elements of Adele's belief about the goals for teaching chemistry, which implies actions that the teacher prioritises in her classes. Adele's teaching knowledge for the component *Guidelines for Science Teaching* sometimes influences behaviours and attitudes (Behavioural Self-concept) such as, for example, changing the planning of the undergraduates' regency for believing that a certain way of working with a content is more adequate than another. About this, undergraduate Erica reports that:

> The professor also suggested some changes to my class and, although I really liked the format of the class, I accepted her suggestions, because I didn't feel comfortable contradicting her, mainly because it's her classes and class hours. Still, I felt that with those changes, even if they were just changes in the order of the class, it became less dynamic and contextualised, because it brings all the chemical concepts first, and then an example of how this concept was important to history. (Erica Supervised Teaching Practice III field diary)

. According to the excerpt above, Adele changes Erica's proposal to a sequence that she feels is more suitable. This behaviour is, in turn, influenced by her beliefs about science learning proposals and by her *Cognitive Self-concept* about the historical aspects of chemistry and how to develop the classes, the educational objectives.

Another teaching knowledge that emerged timidly in the documents analysed was the *Knowledge of Students' Understanding of Science*, which deals with alternative conceptions of a specific content, collective or individual needs and learning difficulties, motivation or interest of students about a topic in science. In this sense, Ivan reports in his Supervised Teaching Practice II field diaries an episode in which this category appears:

> After the example given, the teacher solved the first four questions on the list together with the students, and the students were participating or paying attention. In question four, students would need the concept of polarity to answer it. The teacher asked if anyone remembered, and one student replied: "polar compounds are those that interact with water, right?" The teacher said that we can analyse it this way, but added: "For us here in the classroom, we are going to consider that polarity is linked to a structure having heteroatoms". In my opinion, this was a simple and good explanation, and the students seemed to have understood. (Ivan's Teaching Practice II field diaries)

In the excerpt above, we infer that the teacher, in this class, showed concern for the group's learning the concept of polarity, which is necessary for the line of reasoning proposed by the question - *Knowledge of Students' Understanding of Science*. This is also one of the analysed sections in which there is a mutual influence between the *Knowledge of Students' Understanding of Science* with the category *Behavioural Self-concept*, which co-occurred 19 times.

Generally speaking, this research identified that self-concept and teacher knowledge have a mutual influence and that the categories that emerged corroborate to infer how much the *Affective*, *Cognitive*, and *Behavioural Self-concept* influence Adele when she accesses the knowledge base components for teaching chemistry. In this sense, the main self-influences of self-concept and teaching knowledge involve the *Behavioural Self-concept*, which co-occurred mainly with the *General Pedagogical Knowledge*, *Subject Matter Knowledge*, and *the Knowledge of Instructional Strategies for Science Teaching*.

CONCLUSIONS

In this research, the objective was to understand the possible relationships between teacher knowledge and the self-concept of a basic

education teacher. It was also possible to make inferences about the relationships between components of teaching knowledge of this professional, considering the intrinsic characteristic presented in the *hybrid model*. The relationship between teaching knowledge helped to support the discussions carried out in this investigation and understand how this teacher acts in her school and educational context.

Thus, the analysis of the collected data made it possible to emerge the possible mutual influence between Adele's self-concept and teaching knowledge.

We consider that this research has brought results that can help us understand the mutual influence between experienced teachers' teaching knowledge and self-concept. Briefly, we understand that for the teacher participating in this research, the self-concept that emerged the most was the *Behavioural* and what most co-occurred with components of her teaching knowledge. With this, we infer that the way Adele interacts with her school space strongly influences the way she builds her teaching practice. Some excerpts present in the data collected demonstrate that there is the influence of more than one component of teacher knowledge and self-concept for the pedagogical actions and choices taken by the teacher. The way in which the *Cognitive Self-concept*, mutually influenced by their *General Pedagogical Knowledge* and *Subject Matter Knowledge*, impact their behaviour towards undergraduates presents a practical result of this multiple influence. In a discussion presented, we suggest that the *Cognitive Self-concept* also plays an important role in the perception of the teacher's *Subject Matter Knowledge* for some chemistry contents, and this relationship, in turn, has an important effect on the teacher's actions regarding her professional work.

Considering that there were specific gaps in her education, we infer that a large part of her teaching knowledge comes from her practice and experience built up over the years of work.

There are certainly several other relationships implicit in the complexity involved in a teacher's decision-making, as well as how this professional perceives his/her practice. In this sense, we suggest further research to unveil and understand the knowledge inherent to teaching. In addition to predictors of efficiency and satisfaction in teaching, the discussions that emerged in this and other works can help construct and design new ways of training chemistry teachers, aiming at a detailed look at their self-concept and teaching knowledge. Therefore, this research revealed the importance of

future investigations on the subject and the importance of working with this theme in initial teacher education courses.

ACKNOWLEDGMENTS

To the teacher who kindly accepted to participate in this research.

AUTHORSHIP CONTRIBUTION STATEMENT

K.S.C.N. and I.V.F. conceived the idea of the research presented. I.V.F. collected the data. The two authors (K.S.C.N. and I.V.F.) actively participated in the development of the theory, methodology, organisation and analysis of the data, discussion of results, and approval of the final version of the work.

DATA AVAILABILITY STATEMENT

Data supporting the results of this study will be made available by the corresponding author, I.V.F, upon reasonably previous request.

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