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CONHECIMENTO TECNOLÓGICO PEDAGÓGICO DO CONTEÚDO (TPACK) DE LICENCIANDOS DE QUÍMICA: RESULTADOS DE UM PROGRAMA DE FORMAÇÃO DE PROFESSORES

Pre-service chemistry teachers' technological pedagogical content knowledge (TPACK): findings from a teacher training program design

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Abstract

To integrate digital technologies into the classroom, qualified training of teachers is essential so that future teachers may appropriate the use of digital technologies. To guide the integration of technologies in teaching, the theoretical model called Technological Pedagogical Content Knowledge (TPACK), designed by Mishra and Koehler in 2006, highlights the importance to relate teachers' pedagogical, technological, and content knowledge. This mixed method study aimed to understand how the perceptions of pre-service chemistry teachers related to their Technological Pedagogical Content Knowledge bases (TPACK) are modified when participating in a teacher training program. The pre-service teachers' pre- and post-perceptions of participation were analyzed using a quantitative questionnaire to ten participants and a semi-structured interview with two participants. The results showed that after participating in the training program, the future chemistry teachers demonstrated an increase in self-perception regarding all the TPACK's knowledge bases, mainly regarding Content Knowledge and Pedagogical Content Knowledge. Therefore, the continuity of research supported by the TPACK framework may lead to innovative practices in pre-service teacher education.

Keywords: Pre-service teacher; Chemistry teaching; Educational technologies; TPACK; Mixed Methods.

Resumo

Para integrar as tecnologias digitais à sala de aula, é essencial a formação qualificada de professores, onde estes possam se apropriar do uso de tecnologias digitais. Para nortear a integração de tecnologias ao ensino, o modelo teórico denominado Conhecimento Tecnológico Pedagógico do Conteúdo (TPACK), idealizado por Mishra e Koehler em 2006, destaca a importância de relacionar o conhecimento pedagógico, tecnológico e de conteúdo dos professores. Esse estudo de método misto objetivou compreender como as percepções de licenciandos de química relacionadas às suas bases de Conhecimento Tecnológico Pedagógico do Conteúdo (TPACK) são modificadas ao participarem de um programa de formação docente. As percepções pré e pós-participação dos futuros professores foram analisadas por meio de um questionário quantitativo aplicado a dez participantes e uma entrevista semiestruturada aplicada a dois participantes. Os resultados mostraram que após a participação no programa de formação, os professores em formação inicial demonstraram um aumento na autopercepção em relação a todas as bases de conhecimento do TPACK, principalmente no que diz respeito ao Conhecimento do Conteúdo e ao Conhecimento Pedagógico do Conteúdo. Portanto, a continuidade das pesquisas apoiadas pelo *framework* TPACK pode levar a práticas inovadoras na formação inicial de professores.

Palavras-Chave: Formação inicial; Ensino de Química; Tecnologias educacionais; TPACK; Métodos Mistos.

INTRODUCTION

Teachers' attitudes towards educational technologies may influence chemistry learning and teaching. The chemistry education at the high school allows the students to understand not only chemical transformations and processes but also the construction of scientific knowledge related to technological applications and their environmental, social, political, and economic implications. Considering the contemporary classroom, chemistry teaching to be successfully instructed in the classroom needs to integrate educational technologies to stimulate and enhance learning (Moran, 2000; MEC, 2013; Penn & Ramnarain, 2019).

Camargo and Daros (2018) argue that when the students feel part of the teaching-learning process, through active methodologies and digital technologies, the possibilities for their learning are increased when compared to the traditional teaching methods. Therefore, according to the authors, innovation in education is fundamental and necessary for classroom transformation. To integrate digital technologies into the classroom, qualified training of teachers is essential so that future teachers may appropriate the use of digital technologies (Darling-Hammond & Bransford, 2005; Bransford, Brown, & Cocking, 2007). In the same way, the establishment of public policies that guide teacher training processes in the area of digital technologies is fundamental (Ramos, 2012; Machado, Vasconcelos, & Oliveira, 2017).

Flores (2014) clarifies that teachers must use technology not only as a tool but also to integrate it into their pedagogical practice and the development of the school curriculum. For that reason, teachers need to know what technological resources are available in their work environment and their potential (Ryan, 2013). One can attribute the deficiency in teacher knowledge regarding technology integration, in preservice education programs, to various curriculum factors, which encompass the number, quality, and scope of provided opportunities.

Polly et al. (2010) report that the majority of teacher education programs only offer one course in educational technology that emphasizes basic applications of technology for instruction and management, which are unlikely to have an impact on student learning. Furthermore, these courses are usually provided early on in the pre-service teacher education program, with the expectation that the pre-service teachers will integrate these technologies two to three years later in their future teaching careers. Along with the lack of program depth or coherence, pre-service teachers seldom have opportunities to witness in-service teachers meaningfully integrating technology during their field placements (Belland, 2008).

For pre-service teachers to apply their knowledge of technology to enhance their teaching and their students' literacy learning, they must possess adequate knowledge and confidence in their ability to utilize technology effectively. To develop a sufficient understanding of TPACK, technology integration must be a central aspect of teacher education (Belland, 2008; Polly *et al.*, 2010). This implies that pre-service teachers must not only study effective practices, but must also have sufficient time to explore technology, experience success, collaborate with knowledgeable peers (Ertmer & Ottenbreit-Leftwich, 2010), and witness effective technology integration, where technology is used to aid students in constructing knowledge and solving problems (Belland, 2008). When pre-service teachers have such opportunities, they are more likely to develop a predisposition toward technology integration, which is crucial for teachers to consistently and effectively use technology to advance learning across various curricula (Belland, 2008).

This adherence to the use of technologies has given rise to the production of several kinds of research and theoretical models, such as the Concern-based Adoption Model (CBAM) (Hall & Hord, 1987), the Technology Acceptance Model (TAM) (Davis, Bagozzi, & Warshaw, 1989), the Diffusion of Innovations theory (Rogers, 1995), and the Technological Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006).

The TPACK model is noteworthy as a contemporary model for the field of educational technology research, where its proponents Mishra and Koehler (2006) argue regarding the complex type of interrelationship among technologies with the content and pedagogical processes related to teaching. The authors' main point is that teacher education should be based on how to effectively use technology for their educational goals and not just on how it works.

TPACK: Technological Pedagogical Content Knowledge

Teacher education programs historically have prioritized the development of content knowledge (Veal & MaKinster, 1999) and general pedagogical skills (Ball & McDiarmid, 1990). However, Shulman (1986) argued that separating these knowledge domains is problematic and proposed the concept of pedagogical content knowledge. Shulman believed that simply having knowledge of subject matter and pedagogical strategies does not fully define a good teacher. Instead, he suggested that teachers must possess pedagogical content knowledge to become experts in a specific content area. As technology became more prevalent, educators and researchers recognized the significance of technology in education and its impact on content and pedagogy. Consequently, teachers were expected to gain the knowledge necessary to use technology effectively in their teaching practices.

Throughout time, numerous researchers have endeavored to combine technology with Shulman's concept of pedagogical content knowledge (PCK). Pierson (1999) proposed a theoretical model of technology integration that combined technological knowledge with Shulman's framework. Pierson further argued that technology can only be utilized meaningfully when a teacher sees it as an essential component of the learning process. Margerum-Leys and Marx (2002) suggested that computer technology could enhance student performance. However, they also noted that teachers need to possess extensive and diverse knowledge to effectively use instructional technology in the classroom. These researchers evaluated teachers' knowledge of educational technology based on Shulman's model of content knowledge, pedagogical knowledge, and pedagogical content knowledge. By applying Shulman's model to analyze the data they collected through observations, they proposed a new "knowledge set" that integrated educational technology practices.

For Niess (2005), it was difficult to expect teacher candidates to teach a specific content area using an integrated knowledge structure. Niess highlighted the significance of developing a comprehensive understanding of their subject matter, particularly for science and mathematics teachers, about technology and its role in teaching. Niess coined the term "technology PCK" to describe this particular knowledge base of teachers, where technology is an essential part of the teaching process.

Koehler and Mishra presented the first ideas of the framework entitled Technological Pedagogical Content Knowledge (TPACK) in 2005, as a framework to comprehend the knowledge types needed by teachers to integrate technologies into the curriculum. Hence, the TPACK framework emerges as a reference that allows reflection on the knowledge that guides conceptions and practices in the field of educational technology, whether from the perspective of integrating technologies into the curriculum or from the perspective of teacher training.

The TPACK framework is recognized in the literature as a theoretical-methodological framework that may promote a series of reflections on the integration of technology in education, with the potential to transform teacher education and professional practice (Mishra & Koehler, 2006; Cox, 2008; Angeli & Valanides, 2009; Graham *et al.*, 2009; Abbitt, 2011; Graham, 2011; Kinchin, 2012; Koh & Chai, 2014; Hofer & Harris, 2015; Olofson, Swallow & Neumann, 2016).

According to Mishra and Koehler (2006), TPACK is defined as the combination of three types of knowledge, Pedagogical Knowledge (PK), Content Knowledge (CK), and Technological Knowledge (TK), and their intersections. This combination is graphically represented by a Venn diagram (Figure 1), which emphasizes the interactions between the three knowledge domains.

The combination of these three primary knowledge types results in four additional knowledge types: Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Technological Pedagogical Content Knowledge (TPACK). It is relevant to highlight that all these knowledge types are situated within a context, which includes, for instance, the teachers' beliefs and the school environment (Niess, 2011; Porras-Hernández & Salinas-Amescua, 2013). Due to the integrative approach, the TPACK is not considered a distinct knowledge type, but a knowledge corpus. It may be developed through pedagogical practice or in teacher training programs (Koehler & Mishra, 2009).

From the perspective of the integrative approach, there is a concern about the different knowledge types that compose the framework, since all these knowledge types need to be contemplated in the teacher education process. When analyzing the literature on the framework, it realizes a lack of clarity in defining each one of the knowledge types. Furthermore, the boundaries among the knowledge types that compose the TPACK framework are unclear, being difficult to distinguish in practice (Hsu, 2015).

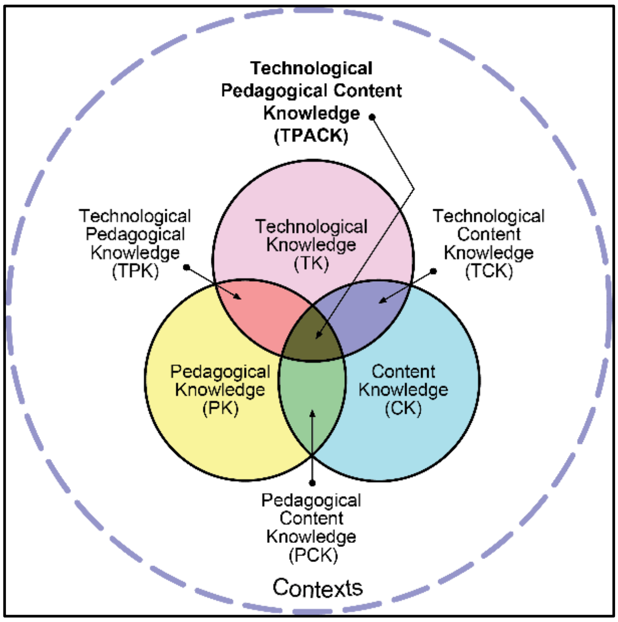

Figure 1 - The components of the TPACK framework. Reproduced by permission of the publisher, ©2012 from http://tpack.org.

In the TPACK framework, technological knowledge is as important knowledge base as pedagogical skills and content knowledge (Mishra & Koehler, 2006). The model proposes the intertwining of three knowledge bases: Content Knowledge, Pedagogical Knowledge, and Technological Knowledge, obtained from the interactions of the following four knowledge bases:

• Content Knowledge (CK): knowledge about concepts and theories related to a subject;

• Pedagogical Knowledge (PK): general pedagogical knowledge, such as classroom management, the use of teaching methodologies, and the students' assessment;

• Technological Knowledge (TK): knowledge and skills needed to use technology, such as program installations, word processors and spreadsheets, and the Internet;

• Technological Content Knowledge (TCK): knowledge of how to represent the contents of a subject with the use of technologies, such as the use of computer simulation for specific content;

• Technological Pedagogical Knowledge (TPK): knowledge of the use of technologies to implement different teaching methods, such as the use of mobile devices app for the application of assessments;

• Pedagogical Content Knowledge (PCK): knowledge of teaching methods (non-technological) related to the content to be taught;

• Technological Pedagogical Content Knowledge (TPACK): knowledge of the use of technologies to implement teaching methods for different contents to be taught.

These seven knowledge bases that compose the TPACK specify a knowledge set required by teachers for the effective integration of technologies in teaching, so important for contemporary education (Mishra and Koehler, 2006; Koh, Chai, and Tsai, 2013; Rolando, 2017).

The TPACK framework serves as a "conceptual lens" that directs attention to specific aspects of educational technology, highlighting relevant issues while disregarding irrelevant ones. As a classification scheme, it offers insights into the nature and relationships among objects, ideas, and actions. However, the real-world application of the framework necessitates the development of sensitive instruments and measures consistent with the theory, and which accurately measure what they intend to measure. Since Mishra and Koehler (2006) first published the TPACK framework, researchers have been developing various TPACK instruments to evaluate the effectiveness of their TPACK-based interventions and professional development efforts in developing teachers' TPACK (Graham *et al.*, 2009; Guzey & Roehrig, 2009). This shift towards measuring TPACK marks a move from the conceptual to the empirical. As researchers increasingly focus on empirically testing the impact of their TPACK-based interventions, accurately capturing their subjects' levels of understanding in TPACK becomes crucial.

Researchers have extensively applied the TPACK framework to different groups, including pre-service teachers (Chai *et al.*, 2011), in-service teachers (Lee & Tsai, 2010), online distance teachers (Archambault & Barnett 2010; Archambault & Crippen, 2009), and teachers in professional development courses (Koehler and Mishra, 2009; Allan *et al.*, 2010). This approach has become an important and effective means of improving science teacher education, by emphasizing the development of teachers' TPACK.

Literature review

Several studies have investigated the integration of technologies into instruction through the TPACK framework. It is possible to identify in the literature different proposals of methods and instruments for the teachers' TPACK assessment. For instance, Schmidt et al. (2009) developed a self-report instrument consisting of 75 items distributed among the seven TPACK domains: 8 TK items, 17 CK items, 10 PK items, 8 PCK items, 8 TCK items, 15 TPK items, and 9 TPACK items. For that instrument, 124 undergraduate students from an American university answered each question using a 1-5 Likert-type scale, where 1 corresponded to "strongly disagree" and 5 corresponded to "strongly agree". According to the authors, the results showed that this instrument is very promising to assess the pre-service teachers' TPACK.

The research of Hsu et al. (2013) presented that TPACK assessment studies tend to address technology in general and that this type of approach may not be able to provide adequate guidelines to improve teacher preparation when teaching with games. Therefore, the authors proposed two new instruments: the first on the Technological Pedagogical Content Knowledge concerning Games (TPACK-G) and the second on the acceptance of Game-Based Learning (GBL). According to the authors, the results showed that both instruments had satisfactory validity and reliability. Furthermore, the teachers' experience with games and their attitudes related to game learning contributed positively to the knowledge of the game itself, as well as to the pedagogical and content knowledge.

Kopcha et al. (2014) showed a multiple case study to evaluate two of the most popular TPACK assessment instruments. The 27 pre-service teachers answered the questionnaire proposed by Schmidt et al. (2009) and had their lesson plans evaluated through the rubric created by Harris et al. (2010). The authors realized that there was a low correlation between the two instruments and a lack of relationship among the TPACK domains. The authors affirm that the fact that different domains exhibit moderate to strong correlations, while similar domains exhibit weak correlations is disconcerting. Nevertheless, they argue that these results are similar to other studies that found contradictions among TPACK measures (So & Kim, 2009; Agyei & Keengwe, 2014). Furthermore, they support a growing concern that the boundaries between TCK, TPK, and other related domains of technology are difficult to establish in practice (Graham, 2011; Brantley-Dias & Ertmer, 2013).

The study by Deng et al. (2017) proposed the TPACK assessment of 280 undergraduate students from a Chinese university. The authors applied the self-report questionnaire by Chai et al. (2011) and the rubric evaluation by Harris et al. (2010). The investigation was applied during an optional course that discussed the use of technology in chemistry instruction. The research showed that the course provided the pre-service chemistry teachers with a greater ability to integrate technologies into the elaborated lesson plans. Despite this, it was realized that the pre-service chemistry teachers could improve their content knowledge and pedagogical knowledge.

Cetin-Dindar et al. (2018) investigated the development of the pre-service chemistry teachers' TPACK. The 17 undergraduate students took a semester-long course and learned to integrate simulations, animations, games, and virtual laboratories into chemistry instruction. Was administrated a questionnaire adapted from Schimdt et al. (2009) and a semi-structured interview, before and after the course. The quantitative and qualitative findings of this study reported that the pre-service chemistry teachers' TPACK partially improved in some components, where gender was not considered a significant variable in technological integration. For further development of the TPACK framework, the authors argue that more context-related technology applications are required in a learning-teaching environment.

Summarily, it may be perceived that there is no singular way to assess TPACK. This is due both to TPACK's theoretical gaps and also to the complex and situated character of this theoretical model. The fact of not having a singular TPACK assessment model may be interpreted as both a potential and a limitation.

Concerning the limitation, not having a pattern of assessment may lead to different interpretations of whether a teacher has developed or has been developing his TPACK. This also leads to difficulty in communication among researchers since they do not have a singular assessment protocol that may be reproduced with different subjects and contexts. On the other hand, this same lack of a definite assessment model allows researchers to develop different assessment instruments that explore different aspects that could not be considered in a singular instrument. Consequently, with a greater number of instruments and evaluation methods, it is easier for researchers to choose and adapt which method and/or instrument will be used to investigate the teachers' TPACK in the expected context (Lawless & Pellegrino, 2007; Harris, Grandgenett & Hofer, 2010; Agyei & Keengwe, 2014).

Research goal

To achieve meaningful teaching and learning, pre-service teachers must integrate the different basis of knowledge typically treated as separate into a unified structure, which is the key to effectively applying TPACK (Mouza & Karchmer-Klein, 2013). According to Koh (2013), teachers generally cannot integrate TPACK in ways that produce meaningful learning with information and communications technology. Thus, this study aimed to integrate the TPACK concept into teacher training using a training program over a semester-long. In this program, pre-service chemistry teachers were asked to develop lesson plans for two content: Atomic Models and Chemical Bonds. The research question addressed by this study was: *how are the perceptions of pre-service chemistry teachers related to their Technological Pedagogical Content Knowledge bases (TPACK) modified when participating in a teacher training program?* The results obtained in the study may guide undergraduate chemistry courses to develop and modernize their curricula and professors/lecturers.

METHODS

Research design and methodology

The research used a quali-quantitative approach, employing mixed methods as a data collection and analysis procedure. This integration of qualitative and quantitative data provides a better understanding of the research problem investigated, compared to the use of separate approaches (Dal-Farra & Fetters, 2017). As pointed out by Fetters, Curry, and Creswell (2013), mixed methods may be implemented at different levels of integration (design, sampling, analysis, and research dissemination).

Among the types of design proposed for research with mixed methods (Dal-Farra & Fetters, 2017), the convergent was considered the most appropriate design for this investigation. The convergent design consists of an approach where separate qualitative and quantitative data are collected and analyzed, then merged and compared or combined with the results obtained (Creswell & Clark, 2018).

The teacher training program

Taking TPACK as a framework that invites reflection on the integration of technologies into the classroom, this experiment implemented a research environment for undergraduate chemistry students in the form of a teacher training program. The program was designed to produce knowledge regarding content, methodological and technological aspects, restricted to a certain number of resources, tools, and teaching methodologies, given the time available.

The teacher training program design was based on the study by Chai, Koh, and Tsai (2010), who proposed a training program in Singapore for 889 pre-service teachers from physics, chemistry, mathematics, literature, English language, Chinese language, and Informatics areas. Similar to these authors, the program sessions were planned to address the TPACK domains separately (PK, CK, TK, and their intersections), integrating them throughout the program.

The program sessions were developed over a semester-long and took 52 hours of activities. The session activities were chosen based on the researchers' experience and the Brazilian university environment. It was chosen different activities to contemplate the pedagogical and technological basis of TPACK. For the content knowledge base, it was chosen two chemistry topics: Atomic Models and Chemical Bonds, due the chemistry topics should correspond to the school year during the teaching internship.

At the end of the activities, the teachers produced a didactic experiment to be applied to their students during their internship, fully integrating technologies with their pedagogic practices. The researchers in addition to implementing the program mediated the training process of the participants also by private moments when requested by them. When the teachers finished their projects, they implemented and tested their projects in their internship practice. Table 1 presents the structure elaborated for the implementation of the teacher training program:

Table 1 - Brief description of the training teacher program content (as guided in Chai, Koh, & Tsai, 2010).

Session	Duration	Activity	TPACK component
1	3 hours	Introduction to the course.	TPACK
		QTPACK questionnaire administration (pre-test).	
		Discussion about the role of educational technology in chemistry instruction.	
2	3 hours	Use of Khan Academy repository to search for educational videos and materials for chemistry instruction (Khan Academy Inc., United States of America, https://www.khanacademy.org).	TCK
		Use of YouTube EDU platform to search for educational videos on chemistry instruction (https://www.youtube.com/c/educacao).	
3	3 hours	Use of PhET Interactive Simulations to teach chemistry in computer simulations (PhET Interactive Simulations, University of Colorado Boulder, https://phet.colorado.edu).	TCK
4	3 hours	Use of IHMC CmapTools software to make conceptual schemes (IHMC CmapTools, Institute for Human & Machine Cognition at The University of West Florida, https://cmap.ihmc.us/cmaptools).	TPK
5	3 hours	Use of Plickers mobile device app to elaborate class tests (Plickers Inc., United States of America - https://get.plickers.com).	TPK
6	3 hours	Use of Google Drive platform (Docs, Sheets, Slides, and Forms) to elaborate online activities.	TK
		Use of Google Classroom to build virtual environments of collaborative learning.	
7	3 hours	Use of Just-in-Time Teaching e Peer Instruction teaching methods (Mazur, 1997; Novak *et al.*, 1999).	PK
		Orientation and discussion regarding the Just-in-Time Teaching and Peer Instruction methodologies combination.	
8	3 hours	Orientation and discussion regarding the lesson plan elaboration to the pre-service teachers' teaching internship.	PCK
9	6 hours	Project #1 planning and elaboration.	TPACK
10	9 hours	Simulated classes to the project #1 application among the pre-service teachers.	TPACK
		Feedback and discussion regarding project #1 simulated classes.	
11	6 hours	Project #2 planning and elaboration.	TPACK
12	4 hours	Project #1 and project #2 applied to the pre-service teachers' teaching internship (activity at the school).	TPACK
13	3 hours	QTPACK questionnaire administration (post-test).	TPACK
		Pre-service teachers interview (Teachers A and B).	
		Conclusion to the course.	

Sample description

The investigation had a sample of ten pre-service chemistry teachers (n = 10, 7 females and 3 males) from a Brazilian university. This sample is characterized as accessibility sampling, which is when the researcher selects the elements that they have access to, considering that these may represent the universe (Gil, 2018). The research participants were all regularly enrolled in the Chemistry Internship III and Chemistry Internship IV subjects in the fall semester of 2019. In that university, the undergraduate chemistry curriculum has 4 subjects for the teaching internship.

In the Chemistry Internship I and Chemistry Internship II subjects, the undergraduate students have their first contact with the school environment, only to observe the chemistry classes at the high school. In the Chemistry Internship III and Chemistry Internship IV subjects, in addition to observation, undergraduate students begin the teaching practice. These last two subjects were chosen by the researchers due they are in the last year of the undergraduate chemistry curriculum. Besides, the internship is a moment of teaching practice for future chemistry teachers.

It is expected that pre-service teachers may naturally apply the technological knowledge and skills learned in teacher training to their future classrooms (Brush *et al.*, 2003). However, simply completing this training may not suffice for effective technology integration to occur in their classrooms. Studies suggest that pre-service teachers still feel ill equipped to use technology effectively in their classrooms (Polly *et al.*, 2010; Tondeur *et al.*, 2013). Thus, carrying out practical training such as teaching internships can be very significant.

Regarding ethical aspects of the study, the 10 pre-service chemistry teachers were previously informed about the investigation and, after agreeing to participate in it, signed a consent term and authorization for use of image, name, and voice. Confidentiality regarding the identity of the participants was maintained through encryption, adopting the identifications as Teacher A and Teacher B to the two interviewees. In addition, the Ethics Committee of the researchers' university approved this research.

Instruments

As this is quali-quantitative research, both quantitative and qualitative data collection instruments were used. The quantitative data were obtained by applying a self-report questionnaire on a 1-7 Likert-type scale both before and after the intervention. The qualitative data were obtained by applying a semi-structured interview after the study of two interviewees.

The questionnaire

In the Brazilian context, the systematic literature review conducted by Rolando, Luz, and Salvador (2015) indicated a lack of research that deals with the application of TPACK to examine teachers' perceptions of the integration of technology in teaching. Most of the existing studies use assessment instruments in English, confirming the need for an instrument validated and reliable in Portuguese to the Brazilian context. Specifically, about chemistry teaching, the systematic literature review conducted by Bernardes e Andrade Neto (2020) also argues about the few studies using the framework TPACK in chemistry teaching. The authors present an overview of how the framework TPACK has been applied to pre-service and in-service chemistry teachers, pointing out that the Brazilian context has not been investigated.

Hence, Rolando (2017) adapted an instrument in Portuguese to measure the seven knowledge bases that compose the TPACK framework. In his study, Rolando examined the international literature for a questionnaire that presented the necessary attributes to go through a process of cross-cultural adaptation. The chosen instrument was the one developed and validated by Chai et al. (2011) and Koh, Chai, and Tsai (2013), more specifically the version presented by the latter, entitled TPACK Survey for Meaningful Learning. This choice was done by testing its properties, which presented evidence of validity and reliability, through factor analysis techniques and internal consistency for the seven knowledge bases of the theoretical model.

After going through the process of cross-cultural adaptation, the version of the questionnaire proposed by Rolando (2017), titled QTPACK, was also tested and presented evidence of validity and reliability to measure the teacher’s perception as shown in Table 2:

Table 2 - Cronbach's alpha reliability scores for each QTPACK component (as cited in Rolando, 2017).

Component	Cronbach's alpha
CK (3 items)	0.85
PK (5 items)	0.85
TK (6 items)	0.85
TCK (3 items)	0.75
TPK (5 items)	0.88
PCK (3 items)	0.85
TPACK (4 items)	0.76

The confirmatory factor analysis showed satisfactory indices of fit of the model (Goodness-of-Fit Measures): $\chi^2 = 906.126$, $\chi^2/df = 2.55$, $p < 0.001$, TLI = 0.91, CFI = 0.92, RMSEA = 0.06). The internal consistency showed a high level of reliability for the set of statements used in the Brazilian version of QTPACK ($\alpha = 0.92$), as well as for the seven knowledge bases.

The QTPACK contains 29 assertions on a 1-7 Likert-type scale (1 = strongly disagree, strongly agree = 7), as presented the Table 3. In each TPACK domain, there is a set of questions regarding the teachers' self-perceptions. Note that the expression "without using technology […]" is adopted on the PCK domain to emphasize that the domain is just about the pedagogical and content knowledge intersection. The present research maintained the questionnaire as well as the author presented.

Table 3 - The QTPACK questionnaire (as cited in Rolando, 2017).

CK - Content Knowledge
CK1 - I have enough knowledge about chemistry. (*Eu possuo conhecimento suficiente sobre química.*) CK2 - I can think about chemistry content as an expert on the subject. (*Eu consigo pensar sobre os conteúdos de química como um expert no assunto.*) CK3 - I can deeply understand the contents of chemistry. (*Eu sou capaz de compreender profundamente os conteúdos de química.*)
PK - Pedagogical Knowledge
PK1 - I can expand my students' thinking skills by creating challenging tasks for them. (*Eu sou capaz de expandir a capacidade de pensar dos meus alunos criando tarefas desafiadoras para eles.*) PK2 - I can guide my students to adopt appropriate learning strategies. (*Eu sou capaz de orientar meus alunos a adotar estratégias de aprendizagem apropriadas.*) PK3 - I can help my students to monitor their learning. (*Eu sou capaz de ajudar meus alunos a monitorar sua própria aprendizagem.*) PK4 - I can help my students to reflect on their learning strategies. (*Eu sou capaz de ajudar meus alunos a refletir sobre suas estratégias de aprendizagem.*) PK5 - I can guide my students to discuss effectively during group work. (*Eu sou capaz de orientar meus alunos a discutir efetivamente durante trabalhos em grupo.*)
TK - Technological Knowledge
TK1 - I have the technical skills to use computers effectively. (*Eu possuo habilidades técnicas para utilizar computadores efetivamente.*) TK2 - I can learn technology easily. (*Eu consigo aprender tecnologia facilmente.*) TK3 - I know how to solve my technical problems when dealing with technology. (*Eu sei resolver meus próprios problemas técnicos quando lido com tecnologia.*) TK4 - I keep up to date on new and important technologies. (*Eu me mantenho atualizado sobre tecnologias novas e importantes.*) TK5 - I can create web pages (websites) on the Internet. (*Eu sou capaz de criar páginas web (sites) na Internet.*)

TK6 - I can use social media (for example, Blog, Wiki, Facebook). (*Eu sou capaz de utilizar mídias sociais, por exemplo, Blog, Wiki, Facebook.*)
PCK - Pedagogical Content Knowledge
PCK1 - Without using technology, I can deal with the most common conceptual errors that my students have in chemistry. (*Sem utilizar tecnologia, eu consigo lidar com os erros conceituais mais comuns que meus alunos possuem em química.*) PCK2 - Without using technology, I know how to select effective teaching approaches to guide students' thinking and learning in chemistry. (*Sem utilizar tecnologia, eu sei como selecionar abordagens de ensino efetivas para orientar o pensamento e a aprendizagem dos alunos em química.*) PCK3 - Without using technology, I can help my students in different ways to understand chemical knowledge. (*Sem utilizar tecnologia, eu consigo, de formas variadas, ajudar meus alunos a compreender o conhecimento químico.*)
TPK - Technological Pedagogical Knowledge
TPK1 - I can use technology to introduce my students to real-world situations. (*Eu sou capaz de usar a tecnologia para introduzir meus alunos em situações do mundo real.*) TPK2 - I can help my students use technology to find more information on their own. (*Eu sou capaz de ajudar meus alunos a utilizar tecnologia para encontrar mais informações por conta própria.*) TPK3 - I can help my students use technology to plan and monitor their learning. (*Eu sou capaz de ajudar meus alunos a utilizar tecnologia para planejar e monitorar sua própria aprendizagem.*) TPK4 - I can help my students use technology to build different forms of knowledge representation (text, graphics, tables, images, videos, comics, etc.). (*Eu sou capaz de ajudar meus alunos a utilizar tecnologia para construir diferentes formas de representação do conhecimento, como texto, gráfico, tabela, imagem, vídeo, história em quadrinhos.*) TPK5 - I can help my students to collaborate using technology. (*Eu sou capaz de ajudar meus alunos a colaborar entre si utilizando tecnologia.*)
TCK - Technological Content Knowledge
TCK1 - I can use computer programs specifically created for chemistry (PhET, ChemSketch, Chemistry LabEscape.) (*Eu consigo usar programas de computador especificamente criados para química, como PhET, ChemSketch, Chemistry LabEscape.*) TCK2 - I can use technologies to research chemistry. (*Eu sou capaz de usar tecnologias para pesquisar sobre química.*) TCK3 - I can use appropriate technologies (for example, multimedia resources, simulators, etc.) to represent the chemistry content. (*Eu consigo utilizar tecnologias apropriadas, por exemplo, recursos multimídia, simuladores, para representar o conteúdo de química.*)
TPACK - Technological Pedagogical Content Knowledge
TPACK1 - I know how to teach classes that effectively combine the content of chemistry, technologies, and teaching approaches. (*Eu sei como dar aulas que combinem de forma efetiva o conteúdo de química, tecnologias e abordagens de ensino.*) TPACK2 - I can select technologies to use in my classroom to enrich what I teach, how I teach, and what students learn. (*Eu consigo selecionar tecnologias para usar em minha sala de aula a fim de enriquecer o que eu ensino, como eu ensino e o que os alunos aprendem.*) TPACK3 - I can use strategies in my classroom that combine chemistry content, technologies, and teaching approaches, as I learned during graduation. (*Eu consigo usar na minha sala de aula estratégias que combinem conteúdo de química, tecnologias e abordagens de ensino, como aprendi durante a graduação.*) TPACK4 - I know how to act as a leader helping people from the schools where I work to coordinate the use of chemistry content, technologies, and teaching approaches. (*Eu sei atuar como líder ajudando pessoas das escolas em que trabalho a coordenar o uso de conteúdo de química, tecnologias e abordagens de ensino.*)

On the 1-7 Likert-type scale used in the questionnaire, scores below 4.00 suggest a lack of self-confidence concerning the assertion, values between 4.00 and 5.00 indicate uncertainty, scores between 5.00 and 6.00 indicate agreement, and scores above 6.00 represent a strong agreement and self-confidence concerning the assertion (Rolando, 2017). This questionnaire was sent to the 10 pre-service chemistry teachers by e-mail as a pre- and post-test. The questions were answered by using a 1-7 Likert-type scale (1 = strongly disagree, strongly agree = 7).

The interview

To deepen the understanding of the quantitative data obtained in the self-report questionnaire, at the end of the intervention was applied a semi-structured interview with two participants. These two interviewees were chosen due to the farthest-apart results observed in the QTPACK and because both pointed out concerns about technological difficulties. The entitled Teacher A was the one with the increasest QTPACK value in the post-test. On the other hand, the entitled Teacher B showed the decreasest QTPACK value in the post-test.

The interview provided information about the application of the project in their teaching internship, being able to discuss and reflect on how participation in the teacher training program changed their TPACK knowledge bases. According to Gil (2018), the interview is one of the most used techniques to collect data in social research, being a way to interact with the investigated context. It can be considered a flexible technique that over the years has contributed to the development of social sciences research.

To apply a semi-structured interview to this research, the following questions were elaborated:

(1) Which elements of the teacher training program were important to you to know and integrate technological knowledge, pedagogical knowledge, and content knowledge effectively in your practice?

(2) Comment on the potentials and limitations of the application of the training program in your internship at school.

(3) How did the application of the teacher training program contribute (or not) to your training as a future chemistry teacher?

The interviewees' answers were recorded in audio for later speech transcription.

Data analysis

The quantitative data from the QTPACK questionnaire were analyzed by the Wilcoxon signed rank test using the IBM SPSS Statistics software (version 26, IBM SPSS, Chicago, IL, USA). The qualitative data obtained in the semi-structured interviews were analyzed based on the Discursive Textual Analysis (DTA) technique by Moraes and Galiazzi (2016).

To verify whether there was a significant difference between the QTPACK pre- and post-test results, the nonparametric Wilcoxon signed rank test was performed. Due to the values obtained in the questionnaire coming from a Likert-type scale, nonparametric tests should be chosen (Bisquerra, Sarriera, & Martinez, 2004). Besides, as the nonparametric equivalent of the paired student's t-test, the Wilcoxon signed rank test can be used as an alternative to the t-test when the population data does not follow a normal distribution. To visualize the mean pre- and post-test values for the investigated group were generated a radar-type graph. Likewise, were generated radar-type graphs for the 2 interviewees. The use of this type of graph to propose a profile of the group/teacher investigated is presented by Colvin and Tomayko (2015), who point out that this way of visualizing the TPACK domains is more efficient and easier to visualize.

The DTA technique by Moraes and Galiazzi (2016) was applied in the speech transcriptions from the semi-structured interviews. The authors guide that the text to be analyzed is called analysis *corpus*. To analyze that corpus, the technique employs three steps: unitarization, categorization, and emergent inference. In the unitarization step, the text obtained is fragmented, obtaining multiple short units. Categorization, in turn, creates relationships among the fragments previously obtained, organizing the units and providing opportunities for new understandings of the data. The emergence of these categories may occur a priori or a posteriori. When it occurs a priori, it means that the construction of categories had already been pre-defined by the researcher, before the analysis process. In the case of being a posteriori, it means that the construction of categories was based on information contained in the data to be analyzed. Finally, in the emerging inferences step occurs the analysis and interpretation, where the researcher makes the called metatext, which expresses the main ideas emerging from the analysis and presents the arguments elaborated by the researcher, who express the new understandings reached (Moraes & Galiazzi, 2016). The metatext made based on the interviewees' answers is present in the Discussion section.

RESULTS

This research designed a teacher training program for pre-service Brazilian chemistry teachers based on the TPACK framework. The proposed training program was designed over 13 Modules in face-to-face meetings, totaling 45 hours of activities. The meetings were held weekly at the University's participants in the fall semester of 2019.

At the beginning of the training program, an initial and informal talking showed that the participants unanimously stated that they had not thought about inserting digital technologies into their plans for the internship that was beginning. Among the allegations, the lack of knowledge about the available resources and the fear of not reaching the objectives regarding the chemical contents stand out.

The modules that made up the program sought to develop activities that addressed all the knowledge involved in the TPACK framework separately, integrating them throughout the program. In the final modules, the elaboration of the training program project encouraged the undergraduates to incorporate digital technologies into their teaching practices, where two lesson plans (1st and 2nd application) were created from the TPACK perspective.

To evaluate the perceptions of pre-service teachers related to their Technological Pedagogical Content Knowledge bases (TPACK), the QTPACK questionnaire was administered pre and post-participation in the training program. In addition, an interview was applied with two participants only post-participation in the training program.

QTPACK questionnaire findings

Data captured from the pre- and post-test was analyzed through descriptive statistics and nonparametric testing within IBM SPSS Statistics software. The complete descriptive statistics can be seen in the Appendix. Table 4 shows the means and standard deviations of the pre and post-test scores:

Table 4 - Results of descriptive statistics for all components in QTPACK.

Component	Pre-test scores		Post-test scores		Significance (p-value)
	Mean	Standard deviation	Mean	Standard deviation	
CK	4.61	0.79	5.20	0.72	0.017
PK	5.02	0.86	5.58	0.63	0.059
TK	5.42	0.83	5.47	0.76	0.813
TCK	5.21	0.92	5.77	0.92	0.090
TPK	5.54	0.67	5.72	0.90	0.439
PCK	4.53	0.94	4.93	0.91	0.042
TPACK	4.95	0.82	5.58	0.81	0.082

A cursory analysis indicates that for the seven knowledge bases, the mean values obtained in the post-study are higher than those obtained in the pre-study did. Also, a significant difference was observed between pre- and post-study results using the Wilcoxon signed rank test.

For the primary bases (PK, CK, and TK) of the TPACK framework, the Wilcoxon signed rank test applied at the 95% confidence level ($p = 0.05$) indicated that there was a significant difference between the pre- and post-study only in the domain CK ($p = 0.017$), adopting the hypothesis that there was a significant difference when p values lower than 0.05 were obtained. For the intermediate bases (PCK, TCK, TPK), the Wilcoxon signed rank test showed a significant difference between the pre- and post-study only in the PCK domain, with $p = 0.042$. Integrating all domains, the TPACK base showed no significant difference between the pre- and post-study, obtaining the value of $p = 0.082$ in the Wilcoxon signed rank test.

It seems that before the training program, chemistry teachers in initial training were more self-conscious of possible limitations on their knowledge bases CK, PK, PCK, and TPACK (scores between 4.00 and 5.00). Moreover, they somehow were less self-conscious of their limited knowledge on TK, TPK, and TCK knowledge bases (scores between 5.00 and 6.00). Among the bases with the lowest average scores (CK, PK, PCK, and TPACK), the base relative to CK (score 4.58) stands out, where the specific statement CK2 had an average low score of 3.83, where they disagreed with the statement that the teacher (they) was an expert in chemistry. In the bases with the highest average scores (TK, TPK, and TCK), the base about the TK (score 5.43) stands out. The statements regarding TK1 (score 6.00) and TK2 (score 6.25) were particularly high, indicating they consider they have good technical skills to use computers and it is easy for them learning a technology.

By observing only the primary knowledge bases CK (score 4.58), PK (score 4.92), and TK (score 5.43), it is easy to see that they have lower self-confidence concerning chemistry content and greater self-confidence in the use of technologies, previously to the intervention. This is also seen if one analyzes the three intermediate knowledge bases PCK, TPK, and TCK. When "content" is integrated into the PK base (score 4.92), the average score drops to 4.56, indicating a low self-confidence of the students in teaching chemistry content. Meanwhile, when technology is integrated into CK (score 4.58) and PK (score 4.92) bases, we do have a higher average score for both, 5.22 and 5.47, respectively. The TPACK base, which contains the intertwining of the primary bases, indicated that teachers in initial training have uncertainty regarding the integration of technologies in teaching. The mean score obtained was 4.88.

In the post-study applied at the end of the training program, despite all the mean scores being higher than those obtained in the pre-study, it appears that the bases that had a more significant increase in confidence (considering p values close to 0.05 in the Wilcoxon signed rank test) were PK ($p = 0.059$), CK ($p = 0.017$) and PCK ($p = 0.042$). Graduates showed limited confidence in these bases (scores between 5.00 and 6.00), having shown some uncertainty concerning these bases (scores between 4.00 and 5.00) before the program. Interestingly, the bases that involve Technology are the ones that showed the least significant difference in the post-study. Figure 2 shows the progress of the pre-service chemistry teachers' TPACK:

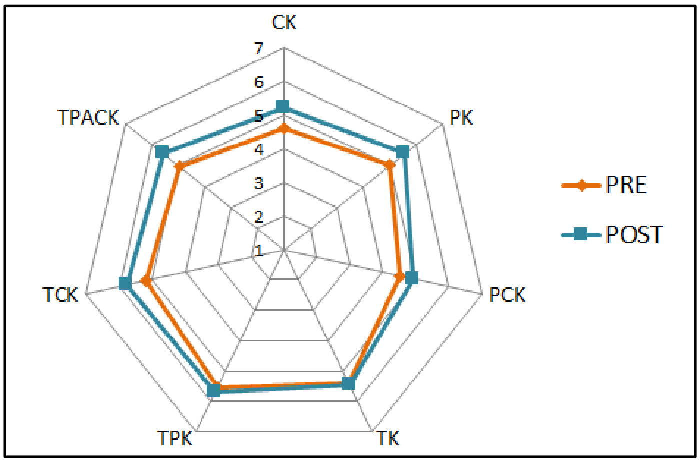

Figure 2 - The mean scores of each component of the TPACK framework for the pre- and post-administration.

Interview findings

The interviews with the two undergraduates (called Teacher A and Teacher B) at the end of the study allowed us to better understand how their perceptions of the TPACK framework were modified when they participated in the training program. The interviews happened after the teachers applied the two lesson plans regarding Atomic Models and Chemical Bonds (named Project #1 and Project #2). The two participants were chosen because they presented very different results in the QTPACK questionnaire and because both pointed out concerns about technological difficulties. Table 5 shows the scores of pre and post-test scores for each interviewee:

Table 5 - QTPACK scores of the interviewees.

Component	Pre-test scores		Post-test scores	
	Teacher A	Teacher B	Teacher A	Teacher B
CK	3.00	4.00	4.00	4.67
PK	4.60	4.80	5.80	4.20
TK	5.33	4.00	5.83	3.67
TCK	4.00	4.43	6.00	3.67
TPK	4.40	5.00	5.60	4.00
PCK	5.33	4.33	5.67	4.33
TPACK	4.00	4.75	5.75	3.75

To better understand the progress of Teacher A and Teacher B, Figure 3 shows the radar-type graphs for both:

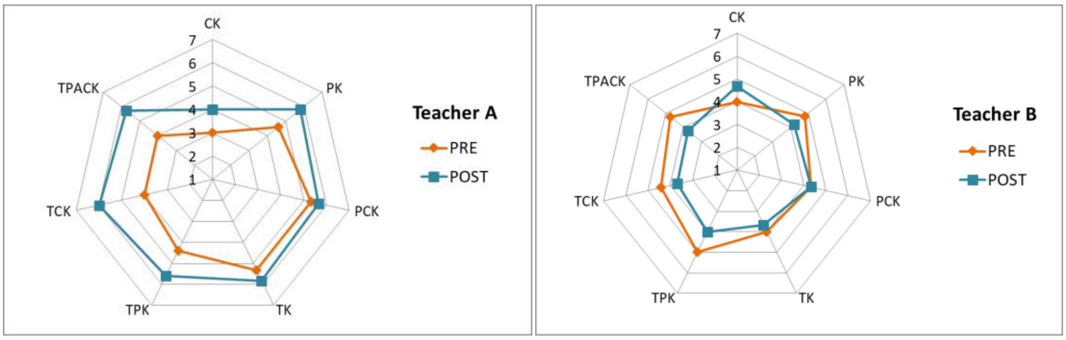

Figure 3 - The mean scores for the pre- and post-test of the interviewees.

While Teacher A presented higher post-test values, Teacher B presented almost all post-test values lower than the pre-test. To present the pre-service teachers developing into the teacher training program, Figure 4, Figure 5, and Figure 6 show two samples of their class planning:

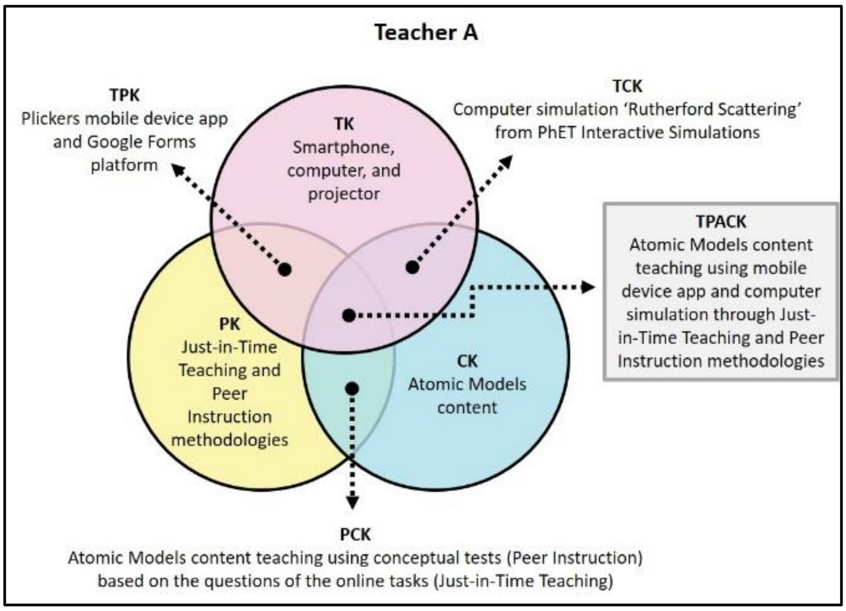

Figure 4 - Sample Teacher A class planning on a TPACK diagram.

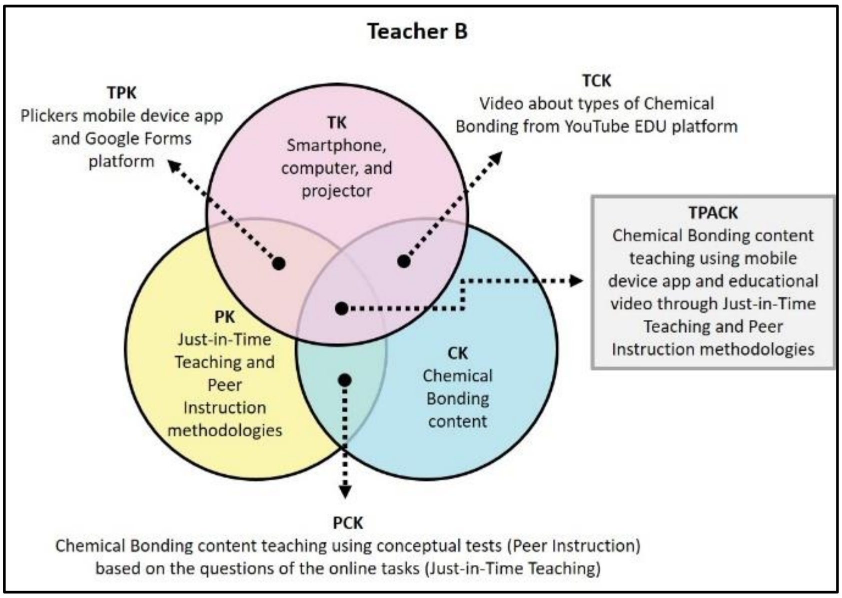

Figure 5 - Sample Teacher B class planning on a TPACK diagram.

Figure 6 - Teachers A and B's class documentation in the teaching internship.

The two interviewees presented very similar lesson plans, so we sought to understand the very different results of the QTPACK questionnaire in the interviews. The individual interview was conducted with three questions, where the main points answered by the interviewees were transcribed into Table 6.

It was observed that Teacher A's self-perception increased by gaining confidence in knowing different technological and pedagogical resources in the program. When planning classes that taught chemistry through digital technology within methodologies, the interviewee said he felt more confident even about the content.

Teacher B, who showed a decrease in self-perception in all domains (except CK), reported that this occurred because he realized that integrating technologies in the classroom was different from what he thought. The decrease in scores was also reported because of difficulties in developing lesson plans. The interviewee reported that he needed help to prepare for the classes and to put them into practice during his internship at school.

Table 6 - Highlighted lines from the interviews.

Semi-structured interview questions	Teacher A answer	Teacher B answer
(1) Which elements of the teacher training program were important to you to know and integrate technological knowledge, pedagogical knowledge, and content knowledge effectively in your practice?	*"What caught my attention in applying the project was the feedback from the students. Because of using the Just-in-Time Teaching and Peer Instruction methodologies, they enjoyed participating more actively in the classes. Online activities did them study the content before school classes, I think that excited them more. Being able to know previously the subject of the class and with easy access by computer or mobile devices created an environment of greater collaboration."*	*"I thought the most important thing about the training program was the use of the Plickers mobile device app. I think that is a very innovative resource, and both the students and I thought it. It gives an immediate result during the application, so I have known how the class's understanding is going. I can keep track of whether or not they have understood the subject I have taught. The Just-in-Time Teaching methodology also caught my attention, because before the class I can know what I need to go deeper into the class, knowing what they have the most difficulty in the subject that will be taught."*
(2) Comment on the potentials and limitations of the application of the training program in your internship at school.	*"To me, the main potential was the possibility of applying the methodologies and technologies learned in the training program to any chemistry content. These are tools that I am going to be able to keep using in my teaching practice. The only limitation I perceive in applying the knowledge gained in the training program is not being able to use digital technologies in every class. Because not everyone has computers, mobile devices, or even the Internet at home. In these cases, it is required to adapt the lesson plan."*	*"I found it difficult to use Plickers in the Peer Instruction methodology and use the projector at school. I realized that I had difficulties dealing with different technologies. It was difficult to deal with this newness at the same time, as I had to deal with the students, who became very agitated when they realized that they would have non-traditional classes. Nevertheless, after I realized how to get by, I found it very easy to teach chemistry contents. I also realized that learning became easier for students. For instance, the students who missed a class were able to retrieve the content by the application of the Peer Instruction methodology."*

Semi-structured interview questions	Teacher A answer	Teacher B answer
(3) How did the application of the teacher training program contribute (or not) to your training as a future chemistry teacher?	*"I did not know about these resources and methodologies until now. It was cool, it was very positive to bring something new to the course. I saw that the students at school liked it a lot. I want to continue using it, I want to continue applying it later in the profession. I ended up choosing the most practical resources to use at school, but in the future, I will try to plan with more time. I want to use some simulations for mobile devices and the program to make the c-maps too. The training program provided a great moment to learn better how to plan the classes for the internship."*	*"I think that the application of the projects contributed a lot to my training as a teacher because I realized that I had difficulties with some things, so it is a sign that I have to prepare myself more regarding it. I have been teaching at high school and the students are young and much faster than I am. Dealing with these methodologies and technologies in the internship contributed a lot to my training. Because I had a little trouble at the beginning, I am glad it was in the internship. Handling that difficulty during the internship is the right moment to improve my skills. So much so that I thought at the beginning of the project that I knew a lot about technologies, but each time I needed help, I realized that it is different to use it to teach. It was a very important learning experience for me."*

DISCUSSION

Considering that a training program was proposed that would enable learning about different technological resources to qualify the pedagogical practice of chemistry teaching, at first it can be considered that the participants of the program already had a good previous knowledge of the technologies addressed and therefore their perceptions surrounding them have not been modified. However, given the observations by the researcher and the reports obtained in the individual interviews, it can be understood that part of the participants indicated greater confidence in the pre-study than was intended (since in the end, they reported not imagining that they would have difficulties in the activities that involved technology), influencing this part of the research that followed a quantitative approach.

This can also be seen in other studies, where researchers have also observed that teachers tend to value themselves too much when they report their practices (Kopcha & Sullivan, 2007; Lawless & Pellegrino, 2007). Rocha and Ricardo (2014) relate this overestimation to self-efficacy beliefs, which are associated with teachers' practices and, especially, with innovative practices. According to the authors, self-efficacy beliefs are seen as judgments of teachers' capabilities, who in this investigation were able to reflect on their capabilities when confronted with questions that contained "I am capable of [...]".

As seen in Teacher B's profile, where the level of confidence about technology was lower after participating in the training program, Pajares and Olaz (2008) point out that people only invest in activities that they believe result in something positive, and when do not achieve the desired result, they tend to become discouraged in the face of difficulties. Fantin and Rivoltella (2013) point out that is essential to critically analyze the use of technology not only as a pedagogical tool but also as an object of study. The incorporation of digital technologies into the curriculum is contingent on the response of the educational context, which is primarily influenced by educational policies that guide the country's educational system.

Koh and Divaharan (2011) advise teacher training that first introduces digital technologies to later work on their integration into teaching, as knowledge related to technologies is generally the scarcest among teachers. However, as observed in the results, the domains most significantly influenced by the program were PK, CK, and PCK, showing that in the investigated context (undergraduates in chemistry at a Brazilian university) there was a greater need to work on issues related to chemical content and pedagogical practices, even for end-of-course undergraduates.

Regarding the decrease in the PK score when the chemical contents were incorporated (PCK) and the increase in the scores referring to PK and CK when technologies were incorporated (TPK and TCK), Pamuk (2011) alike reported that although pre-service teachers indicated development in their core knowledge domains (TK, CK, and PK), without sufficient teaching experience, they had difficulties developing the integrated knowledge domains (like PCK). Rohaan et al. (2012) pointed out that more experience in teaching technology-related knowledge during classes may stimulate the development of pre-service teachers' PCK, which leads to more confidence in teaching and more positive attitudes. Also, Kabakci Yurdakul and Çoklar (2014) and Ozgun-Koca (2009) identified similar research findings about TK: technology usage by pre-service teachers increased significantly and had a positive impact on TPACK domains.

Malaquias and Peixoto (2016) caution against the prevalent teacher training in Brazil, which primarily focuses on the technical aspects of digital technologies. Typically, digital technology use is taught as a separate course in the curriculum, without integration into the content taught in other courses. This approach leads to a merely instrumental use of technology, which can vary widely across Brazil. The choice of a theoretical framework for a training program affects its objectives, contents, and methodologies for teaching and learning plans. In the end, a dynamic and interactive relationship must exist between them (Demir, 2011). Effective professional development for teachers to integrate digital technologies into their teaching practice at the university level is only possible if it aligns with the educational system and school context, and enhances their pedagogical skills.

Teacher training involving technologies proposed by the TPACK framework is seen as an approach that meets the needs of contemporary teachers. Because it makes it possible to relate the technical and pedagogical dimensions within a given area of knowledge. Malaquias and Peixoto (2016) warn that most teacher training focuses on the technical aspects of digital technologies, resulting in the merely instrumental use of these technologies. The theoretical framework chosen for a training program interferes with the objectives, contents, and teaching and learning methodologies planned for the training which, at the end of it, must present a dynamic and interactive relationship with each other (Demir, 2011).

The professional improvement of the teacher while still at the university concerning the integration of digital technologies into teaching is seen as effective only if it provides the qualification of pedagogical practice in line with the educational system and school context. In this way, roles in the classroom end up being transformed, so that teachers go beyond the domain of pedagogical content knowledge, starting to act as mediators, and students become more engaged in their learning process.

In this context, it can be seen that the use of digital technologies can change the relationship between all the subjects involved in the teaching and learning process, where the development of digital culture from initial training makes it possible to overcome the challenges commonly encountered in the school environment (Amante, 2011).

CONCLUSIONS

This study focused on examining perceptions of pre-service chemistry teachers related to their Technological Pedagogical Content Knowledge bases (TPACK). It compared the perceptions before and at the end of a teacher training program. There was a significant increase in confidence related to Content Knowledge (CK) and Pedagogical Content Knowledge (PCK). This higher self-perception after going through the program can be attributed to addressing previous insecurities with the content and methodologies that occurs due to inexperience in the classroom since those investigated were starting their practice in the internships themselves. Hence, studies that provide teacher training for the adequate ability of content and pedagogical practice are as necessary as studies related to the integration of technologies. Because it is clear that even end-of-course undergraduates need training in all those knowledge, as proposed by the TPACK framework.

The knowledge bases that involved the technology presented higher average scores only in the pre-study, not being observed a significant increase in the post-study, indicating higher confidence in using it in the classroom even before the program. This facility in using technology pointed out only at the beginning of the study, was guided in an integrated way to the specific contents, being able to circumvent the other difficulties pointed out by the undergraduates throughout the program. Therefore, the previous conception that integrating technology into their teaching practices was easy most likely was effectively seen as harder than anticipated by the teachers in training.

Despite this, it was considered that the applied study provided experiences that contributed to the training of undergraduates participating in the program. Through this, future teachers were able to obtain knowledge about teaching methodologies with the use of digital technologies for chemistry teaching and had the opportunity to develop skills and abilities necessary for the exercise of the profession demanded by contemporary society.

As seen in the interviewees' statements, Leite (2015) discusses the need to include one or more subjects that address educational technologies in teacher training courses. This would allow graduates to arrive at schools mastering the skills and knowledge necessary for the effective integration of technologies in teaching.

The results on the perceptions of undergraduates in chemistry about the bases of TPACK indicate that the continuity of research supported by this framework can lead to innovative practices regarding the initial training of teachers, as results such as those presented in this investigation can guide undergraduate courses to develop and update their curricula and trainers.

These pre-service chemistry teachers' perceptions findings about TPACK suggest that: (I) teaching institutions still require to address how pre-service teachers are being qualified to use and integrate technology into their classes, and (II) teacher training programs must work to further develop and incorporate methods that better infuse technology throughout the entire teacher training program and across content areas.

To handle these necessities, Tondeur et al. (2013) indicate that rather than focusing on how to use technology, pre-service teachers must learn about how technology can be used for teaching and learning. Niess (2005) guides that teacher training programs develop a multidimensional approach, which concentrates on pre-service teachers' development in teaching a certain subject area with technology each semester.

LIMITATIONS AND FUTURE RESEARCH

As with any research, this study has limitations that should be considered by readers. First, the small number of obtained participants for a mixed methods study, especially the interviewees. Secondly, the duration of just 52 hours of the teacher training program. Thirdly, there is no predictive outcome from the results that could indicate that the training program designed causes pre-service chemistry teachers to effectively, in the end, integrate technology into practice once they become in-service chemistry teachers. Wherefore, the researchers suggest for future research that the training program proposed here may be expanded. Other technological tools and didactic procedures could be added, expanding the training program, as well as applying the investigation to a larger number of teachers from different knowledge fields. Furthermore, the monitoring of a teacher group during and after their undergraduate degree could provide complementary and comparative data between pre-service and in-service education.

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REFERENCES

Abbitt, J. T. (2011). Measuring technological pedagogical content knowledge in preservice teacher education. *Journal of Research on Technology in Education*, *43*(4), 281-300. https://doi.org/10.1080/15391523.2011.10782573

Agyei, D. D., & Keengwe J. (2014). Using technology pedagogical content knowledge development to enhance learning outcomes. *Education and Information Technologies*, *19*(1), 155-171. https://doi.org/10.1007/s10639-012-9204-1

Allan, W. C., Erickson, J. L., Brookhouse, P., & Johnson, J. L. (2010). Teacher professional development through a collaborative curriculum project - an example of TPACK in Maine. *TechTrends*, *54*(6), 36-43. https://doi.org/10.1007/s11528-010-0452-x

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education*, *52*(1), 154-168. https://doi.org/10.1016/j.compedu.2008.07.006

Archambault, L. M., & Barnett J. H. (2010). Revisiting technological pedagogical content knowledge: exploring the TPACK framework. *Computures & Education*, *55*, 1656-1662. https://doi.org/10.1016/j.compedu.2010.07.009

Archambault, L. M., & Crippen, K. (2009). Examining TPACK among K-12 online distance educators in the United States. *Contemporary issues in technology and teacher education*, *9*(1), 71-88. Retrieved from https://citejournal.org/volume-9/issue-1-09/general/examining-tpack-among-k-12-online-distance-educators-in-the-united-states

Ball, D. L., & McDiarmid, G. W. (1990). The subject matter preparation of teachers. In W. R. Houston, M. Haberman & J. Sikula (Eds.), *Handbook of Research on teacher education*. New York, NY, United States of America: Macmillan. Retrieved from http://pubs.sciepub.com/education/3/4/18/index.html#

Belland, B. R. (2008). Using the theory of habitus to move beyond the study of barriers to technology integration. *Computers & Education*, *52*, 353-364. https://doi.org/10.1016/j.compedu.2008.09.004

Bernardes, T. S., & de Andrade Neto, A. S. (2020). Technological pedagogical content knowledge (TPACK) in pre-service and in-service chemistry teacher training: a systematic literature review. *RENOTE*, *18*(2), 611-620. https://doi.org/10.22456/1679-1916.110304

Bisquerra, R., Sarriera, J. C., & Martinéz, F. (2004). *Introdução à estatística: enfoque informático com o pacote estatístico SPSS* [Introduction to statistical: computing approach with the SPSS statistical package]. Porto Alegre, RS: Artmed.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2007). *Como as pessoas aprendem. Cérebro, mente, experiência e escola* [How people learn. Brain, mind, experience, and school]. São Paulo, SP: Senac.

Brantley-Dias, L., & Ertmer, P. A. (2013). Goldilocks and TPACK: is the construct 'just right?''. *Journal of Research on Technology in Education*, *46*(2), 103-128. https://doi.org/10.1080/15391523.2013.10782615

Brush, T., Glazewski, K., Rutowski, K., Berg, K., Stromfors, C., Van-Nest, M. H., Stock, L., & Sutton, J. (2003). Integrating technology into a field-based teacher training programme: the project. *Journal of Educational Technology Research and Development*, *51*(1), 57-72. Retrieved from https://www.jstor.org/stable/30220363

MEC - Ministério da Educação e do Desporto (2013). *Diretrizes curriculares nacionais gerais da educação básica* [National curriculum guidelines for basic education]. Brasília, DF: MEC/SEF. Retrieved from http://portal.mec.gov.br/docman/junho-2013-pdf/13448-diretrizes-curiculares-nacionais-2013-pdf

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: how knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*(3), 255-284. https://doi.org/10.1080/15391523.2010.10782551

Camargo, F., & Daros, T. (2018). *A sala de aula inovadora: estratégias pedagógicas para fomentar o aprendizado ativo* [The innovative classroom: pedagogical strategies to foster active learning]. Porto Alegre, RS: Penso.

Cetin-Dindar, A., Boz, Y., Sonmez, D. Y., & Celep, N. D. (2018). Development of pre-service chemistry teachers' technological pedagogical content knowledge. *Chemistry Education Research and Practice*, *19*(1), 167-183. https://doi.org/10.1039/C7RP00175D

Ching, S. C., Koh, J. H. L., Tsai, C.-C., Tan, L. L. W. (2011). Modeling primary school pre-service teachers' technological pedagogical content knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education*, *57*(1), 1184-1193. https://doi.org/10.1016/j.compedu.2011.01.007

Chai, C. S., Koh, J. H., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Educational Technology & Society*, *13*(4), 63-73. Retrieved from https://eric.ed.gov/?id=EJ909933

Chamberlain, J. M., Lancaster, K., Parsonb, R., & Perkins, K. K. (2014). How guidance affects student engagement with an interactive simulation. *Chemistry Education Research and Practice*, *15*(4), 628-638. https://doi.org/10.1039/C4RP00009A

Colvin, J. C., & Tomayko, M. C. (2015). Putting TPACK on the radar: a visual quantitative model for tracking growth of essential teacher knowledge. *Contemporary Issues in Technology and Teacher Education*, *15*(1), 68-84. Retrieved from https://www.learntechlib.org/primary/p/147870

Cox, S. (2008). *A conceptual analysis of technological pedagogical content knowledge*. Doctoral dissertation. Brigham Young University. Retrieved from https://scholarsarchive.byu.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=2481&context=etd

Creswell, J. W., & Clark, V. L. P. (2018). *Designing and conducting mixed methods research*. (3rd ed.) Los Angeles, United States of America: Sage.

Dal-Farra, R. A., & Fetters, M. D. (2017). Recentes avanços nas pesquisas com métodos mistos: aplicações nas áreas de educação e ensino [Recent advances in mixed methods research: applications in the education and teaching areas]. *Acta Scientiae*, *19*(3), 466-492. Retrieved from http://www.periodicos.ulbra.br/index.php/acta/article/view/3116/2368

Darling-Hammond, L., & Bransford, J. (2005). *Preparing teachers for a changing world: what teachers should learn and be able to do*. San Francisco, United States of America: John Wiley & Sons.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, *35*(8), 982-1003. Retrieved from https://www.jstor.org/stable/2632151

Deng, F., Chai, C. S., So, H.-J., Qian, Y., & Chen, L. (2017). Examining the validity of the technological pedagogical and content knowledge (TPACK) framework for preservice chemistry teachers. *Australasian Journal of Educational Technology*, *33*(3), 1-14. https://doi.org/10.14742/ajet.3508

Fetters, M. D., Curry, L. A., & Creswell, J. W. (2013). Achieving integration in mixed methods designs - principles and practices. *Health Service Research*, *48*(6), 2134-2156. https://doi.org/10.1111/1475-6773.12117

Flores, E. (2014). *Tecnologias na Educação: ensinando e aprendendo com as TIC - uma proposta para educação do campo* [Technologies in education: teaching and learning with ICT - a proposal for countryside education]. Porto Alegre, RS: SEE/RS.

Gil, A. C. (2018). *Métodos e técnicas de pesquisa social* [Methods and techniques of social research]. São Paulo, SP: Atlas.

Graham, C. R., Burgoyne, N., Cantrell, P., Smith, L., St. Clair, L., & Harris, R. (2009). TPACK development in science teaching: measuring the TPACK confidence of inservice science teachers. *TechTrends*, *53*(5), 70-79. https://doi.org/10.1007/s11528-009-0328-0

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, *57*(3), 1953-1960. https://doi.org/10.1016/j.compedu.2011.04.010

Guzey, S. S., & Roehrig, G. H. (2009). Teaching science with technology: case studies of science teachers' development of technology, pedagogy, and content knowledge. *Contemporary Issues in Technology and Teacher Education*, *9*, 25-45. Retrieved from https://citejournal.org/volume-9/issue-1-09/science/teaching-science-with-technology-case-studies-of-science-teachersdevelopment-of-technology-pedagogy-and-content-knowledge

Harris, J. B., Hofer, M. J., Schmidt, D. A., Blanchard, M.R., Grandgenett, N., & Van Olphen, M. (2010). "Grounded" technology integration: instructional planning using curriculum-based activity type taxonomies. *Journal of Technology and Teacher Education*, *18*(4), 573-605. Retrieved from https://digitalcommons.unomaha.edu/tedfacpub/40/

Harris, J. B., Grandgenett, N., & Hofer, M. (2010). Testing a TPACK-based technology integration assessment rubric. In Gibson, D. and Dodger, B. (orgs.), *Proceedings of Society for Information Technology & Teacher Education International Conference*. Chesapeake: AACE, 3833-3840. Retrieved from https://scholarworks.wm.edu/bookchapters/6

Hofer, M., & Harris, J. (2015). Developing TPACK with learning activity types. In Hofer, M., Bell, L., & Bull, G. (eds.), *Practitioner's Guide to Technology, Pedagogy, and Content Knowledge (TPACK): Rich Media Cases of Teacher Knowledge*. Waynesville: AACE, 1-14. Retrieved from https://scholarworks.wm.edu/book/1/

Hsu, Y. S. (2015). *Development of science teachers' TPACK: East Asian practices*. Singapore: Springer.

Hsu, C.-Y., Liang, J.-C., Chai, C.-S., & Tsai, C.-C (2013). Exploring preschool teachers' technological pedagogical content knowledge of educational games. *Journal of Educational Computing Research*, *49*(4), 461-479. https://doi.org/10.2190/EC.49.4.c

Kabakci Yurdakul, I., & Çoklar, A. N. (2014). Modeling preservice teachers' TPACK competencies based on ICT usage. *Journal of Computer Assisted Learning*, *30*(4), 363-376. https://doi.org/10.1111/jcal.12049

Kinchin, I. (2012). Avoiding technology-enhanced non-learning. *British Journal of Educational Technology*, *43*(2), 43-48. https://doi.org/10.1111/j.1467-8535.2011.01264.x

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60-70. Retrieved from https://citejournal.org/volume-9/issue-1-09/general/what-is-technological-pedagogicalcontent-knowledge

Koh, J. H. L. (2013). A rubric for assessing teachers' lesson activities with respect to TPACK for meaningful learning with ICT. *Australasian Journal of Educational Technology*, *29*(6), 887-900. https://doi.org/10.14742/ajet.228

Koh, J. H. L., & Chai, C.S. (2014). Teacher clusters and their perceptions of technological pedagogical content knowledge (TPACK) development through ICT lesson design. *Computers & Education*, *70*, 222-232. https://doi.org/10.1016/j.compedu.2013.08.017

Koh, J. H. L., & Divaharan, H. (2011). Developing pre-service teachers' technology integration expertise through the TPACK-developing instructional model. *Journal of Educational Computing Research*, *44*(1), 35-58. https://doi.org/10.2190/EC.44.1.c

Koh, J. H. L., Chai, C. S., & Tsai, C.C. (2013). Examining practicing teachers' perceptions of technological pedagogical content knowledge (TPACK) pathways: a structural equation modeling approach. *Instructional Science*, *41*(4), 793-809. https://doi.org/10.1007/s11251-012-9249-y

Kopcha, T. J., Ottenbreit-Leftwich, A., Jung, J., & Baser, D. (2014). Examining the TPACK framework through the convergent and discriminant validity of two measures. *Computers & Education*, *78*, 87-96. https://doi.org/10.1016/j.compedu.2014.05.003

Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research*, *77*(4), 575-614. https://doi.org/10.3102/0034654307309921

Lee M. H., & Tsai C. C. (2010). Exploring teachers' perceived self efficacy and technological pedagogical content knowledge with respect to educational use of the World Wide Web. *Instructional Science*, *38*, 1-21. https://doi.org/10.1007/s11251-008-9075-4

Machado, J. C., Vasconcelos, M. C. C., & Oliveira, N. R. (2017). Formação inicial e continuada de professores: entre o discurso e a prática [Pre-service and in-service teacher education: between the discourse and the practice]. *Cadernos de Educação, Tecnologia e Sociedade*, *10*(1), 13-27. http://dx.doi.org/10.14571/cets.v10.n1.13-27

Malaquias, A., & Peixoto, J. (2016). Formação de professores para o uso de tecnologias na educação: a visão dos professores do estado de Goiás [Teacher training for the use of technologies in education: the view of teachers in the state of Goiás]. *Ciclo Revista: Vivências em Ensino e Formação*, *1*(2), 1-7. Retrieved from https://periodicos.ifgoiano.edu.br/ciclo/article/view/221

Margerum-Leys, J., & Marx, R. W. (2002). Teacher knowledge of educational technology: a study of student teacher/mentor teacher pairs. *Journal of Educational Computing Research*, *26*(4), 427-462. https://doi.org/10.2190/JXBR-2G0G-1E4T-7T4M

Mazur, E. (1997). Peer instruction: *A user's manual*. New Jersey, United States of America: Prentice Hall.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Moraes, R., & Galiazzi, M. C. (2016). *Análise textual discursiva* [Discursive textual analysis]. (2nd ed.). Ijuí, RS: Unijuí.

Moran, J. M. (2000). Ensino e aprendizagem inovadores com tecnologias [Innovative teaching and learning with technologies]. *Informática na educação: Teoria & Prática*, *3*(1), 137-144. https://doi.org/10.22456/1982-1654.6474

Mouza, C. & Karchmer-Krein, R. (2013). Promoting and assessing pre-service teachers' technological pedagogical content knowledge (TPACK) in the context of case development. *Journal of Educational Computing Research*, *48*(2), 127-152. https://doi.org/10.2190/EC.48.2.b

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509-523. https://doi.org/10.1016/j.tate.2005.03.006

Niess, M. L. (2011). Investigating TPACK: Knowledge growth in teaching with technology. *Journal of Educational Computing Research*, *44*(3), 299-317. https://doi.org/10.2190/EC.44.3.c

Novak, G., M., Patterson, E., Gavrin, A., & Christian, W. (1999). *Just-in-time teaching: blending active learning with web technology*. New Jersey, United States of America: Prentice Hall.

Olofson, M. W., Swallow, M. J., & Neumann, M. D. (2016). TPACKing: A constructivist framing of TPACK to analyze teachers' construction of knowledge. *Computers & Education*, *95*, 188-201. https://doi.org/10.1016/j.compedu.2015.12.010

Ozgun-Koca, S. A. (2009). The views of preservice teachers about the strengths and limitations of the use of graphing calculators in mathematics instruction. *Journal of Technology and Teacher Education*, *17*(2), 203-227. Retrieved from https://www.learntechlib.org/primary/p/26268/

Pajares, F., & Olaz, F. (2008). Teoria social cognitiva e auto-eficácia: uma visão geral. Teoria social cognitiva: conceitos básicos [Social cognitive theory and self-efficacy: an overview. Cognitive social theory: basic concepts]. Porto Alegre, RS: Artmed.

Penn, M., Ramnarain, U. (2019). South African university students' attitudes towards chemistry learning in a virtually simulated learning environment. *Chemistry Education Research and Practice*, *20*(4), 699-709. https://doi.org/10.1039/C9RP00014C

Pierson, M. E. (1999). *Technology integration practice as a function of pedagogical expertise*. (Doctoral dissertation). Arizona State University. https://doi.org/10.1080/08886504.2001.10782325

Polly, D., Mims, C., Shepherd, C. E., Inan, F. (2010). Evidence of impact: transforming teacher education with preparing tomorrow's teachers to teach with technology (PT3) grants. *Teaching and teacher education*, *26*(4), 863-870. https://doi.org/10.1016/j.tate.2009.10.024

Porras-Hernández, L. H., Salinas-Amescua, B. (2013). Strengthening TPACK: A broader notion of context and the use of teacher's narratives to reveal knowledge construction. *Journal of Educational Computing Research*, *48*(2), 223-244. https://doi.org/10.2190/EC.48.2.f

Ramos, M. R. V. (2012). O uso de tecnologias em sala de aula [The use of technologies in the classroom]. *Revista Ensino de Sociologia em Debate*, *1*(2), 1-16. Retrieved from http://www.uel.br/revistas/lenpes-pibid/pages/edicao-nordm.-2-vol.-1-jul-dez-2012.php

Rivoltella, P. C., & Fantin, M. (Orgs.) (2013). Cultura digital e escola: pesquisa e formação de professores [Digital culture and school: research and teacher training]. Campinas, SP: Papirus.

Rolando, L. G. R. (2017). *Um exame da percepção de professores de biologia acerca de suas bases de conhecimento tecnológico pedagógico do conteúdo* [An examination of the Biology teachers' perception about their technological pedagogical content knowledge]. (Doctoral dissertation). Instituto Oswaldo Cruz. Retrieved from https://www.arca.fiocruz.br/handle/icict/23820

Rolando, L. G. R., Luz, M. R. M. P., & Salvador, D. F. (2015). O conhecimento tecnológico pedagógico do conteúdo no contexto lusófono: uma revisão sistemática de literatura [The technological pedagogical content knowledge in lusophone context: a systematic review of the literature]. *Revista Brasileira de Informação na Educação*, *23*(3), 174-190. https://doi.org/10.4025/imagenseduc.v7i2.34615

Ryan, B. J. (2013). Line up, line up: using technology to align and enhance peer learning and assessment in a student centred foundation organic chemistry module. *Chemistry Education Research and Practice*, *14*(3), 229-238. https://doi.org/10.1039/C3RP20178C

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK): the development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 123-149. https://doi.org/10.1080/15391523.2009.10782544

Shulman, L. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14. Retrieved from https://www.jstor.org/stable/1175860

So, H., & Kim, B. (2009). Learning about problem based learning: student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology*, *25*(1), 101-116. https://doi.org/10.14742/ajet.1183

Tondeur, J., Roblin, N .P, Braak, J., Fisser, P., & Voogt, J. (2013). Technological pedagogical content know- ledge in teacher education: in search of a new curriculum. *Educational Studies*, *39*(2), 239-243. https://doi.org/10.1080/03055698.2012.713548

Veal, W. R., & MaKinster, J. G. (1999). Pedagogical content knowledge taxonomies. *Electronic Journal of Science Education*, *3*(4). Retrieved from https://ejrsme.icrsme.com/article/view/7615

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APPENDIX: WILCOXON SIGNED RANK TEST APPLIED TO QTPACK PRE AND POST-TEST IN IBM SPSS STATISTICS SOFTWARE (VERSION 26, IBM SPSS, CHICAGO, IL, USA).

CK - Content Knowledge								
Descriptive Statistics								
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
PRE	10	4.6100	0.79975	3.00	6.00	4.2475	4.6700	5.0825
POST	10	5.2010	0.72405	4.00	6.67	4.6700	5.1650	5.6700

Wilcoxon Signed-Rank Test - CK				
		N	Mean Rank	Sum of Ranks
POST - PRE	Negative Ranks	1[a]	2.50	2.50
	Positive Ranks	8[b]	5.31	42.50
	Ties	1[c]	-	-
	Total	10	-	-

a. POST < PRE
b. POST > PRE
c. POST = PRE

Test Statistics[a]	
	POST - PRE
Z	-2.382[b]
Sig. asymp. (bilateral)	0.017

a. Wilcoxon Signed-Rank Test
b. Based on negative ranks

PK - Pedagogical Knowledge								
Descriptive Statistics								
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
PRE	10	5.020	0.8561	3.6	6.6	4.450	5.000	5.600
POST	10	5.580	0.6286	4.2	6.4	5.150	5.800	6.000

Wilcoxon Signed-Rank Test - PK				
		N	Mean Rank	Sum of Ranks
POST - PRE	Negative Ranks	2[a]	4.50	9.00
	Positive Ranks	8[b]	5.75	46.00
	Ties	0[c]	-	-
	Total	10	-	-

a. POST < PRE
b. POST > PRE
c. POST = PRE

Test Statistics[a]	
	POST - PRE
Z	-1.889[b]
Sig. asymp. (bilateral)	0.059

a. Wilcoxon Signed-Rank Test
b. Based on negative ranks

PCK - Pedagogical Content Knowledge								
Descriptive Statistics								
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
PRE	10	4.5330	0.94538	3.00	6.00	3.5850	4.8350	5.0825
POST	10	4.9330	0.91406	3.33	6.00	4.1650	5.0000	5.7525

Wilcoxon Signed-Rank Test - PCK				
		N	Mean Rank	Sum of Ranks
POST - PRE	Negative Ranks	0[a]	0.00	0.00
	Positive Ranks	5[b]	3.00	15.00
	Ties	5[c]	-	-
	Total	10	-	-

a. POST < PRE
b. POST > PRE
c. POST = PRE

Test Statistics[a]	
	POST - PRE
Z	-2.032[b]
Sig. asymp. (bilateral)	0.042

a. Wilcoxon Signed-Rank Test
b. Based on negative ranks

TK - Technological Knowledge								
Descriptive Statistics								
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
PRE	10	5.4210	0.82755	4.00	6.33	4.6700	5.4400	6.3300
POST	10	5.4660	0.75585	3.67	6.50	5.2475	5.5850	5.8725

Wilcoxon Signed-Rank Test - TK				
		N	Mean Rank	Sum of Ranks
POST - PRE	Negative Ranks	3[a]	6.83	20.50
	Positive Ranks	6[b]	4.08	24.50
	Ties	1[c]	-	-
	Total	10	-	-

a. POST < PRE
b. POST > PRE
c. POST = PRE

Test Statistics[a]	
	POST - PRE
Z	-0.237[b]
Sig. asymp. (bilateral)	0.813

a. Wilcoxon Signed-Rank Test
b. Based on negative ranks

TPK - Technological Pedagogical Knowledge								
Descriptive Statistics								
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
PRE	10	5.540	0.6670	4.4	6.6	5.000	5.500	6.050
POST	10	5.720	0.9004	4.0	7.0	5.050	6.000	6.400

Wilcoxon Signed-Rank Test - TPK				
		N	Mean Rank	Sum of Ranks
POST - PRE	Negative Ranks	3[a]	5.33	16.00
	Positive Ranks	6[b]	4.83	29.00
	Ties	1[c]	-	-
	Total	10	-	-

a. POST < PRE
b. POST > PRE
c. POST = PRE

Test Statistics[a]	
	POST - PRE
Z	-0.773[b]
Sig. asymp. (bilateral)	0.439

a. Wilcoxon Signed-Rank Test
b. Based on negative ranks

TCK - Technological Content Knowledge								
Descriptive Statistics								
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
PRE	10	5.2090	0.92278	4.00	6.67	4.3225	5.1650	6.0825
POST	10	5.7680	0.91636	3.67	7.00	5.5025	6.0000	6.1675

Wilcoxon Signed-Rank Test - TCK				
		N	Mean Rank	Sum of Ranks
POST - PRE	Negative Ranks	1[a]	4.00	4.00
	Positive Ranks	6[b]	4.00	24.00
	Ties	3[c]	-	-
	Total	10	-	-

a. POST < PRE
b. POST > PRE
c. POST = PRE

Test Statistics[a]	
	POST - PRE
Z	-1.696[b]
Sig. asymp. (bilateral)	0.090

a. Wilcoxon Signed-Rank Test

TPACK - Technological Pedagogical Content Knowledge								
Descriptive Statistics								
	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
PRE	10	4.9500	0.82327	4.00	6.25	4.1875	4.7500	5.6875
POST	10	5.5750	0.80838	3.75	7.00	5.3750	5.7500	5.7500

Wilcoxon Signed-Rank Test - TPACK				
		N	Mean Rank	Sum of Ranks
POST - PRE	Negative Ranks	2[a]	5.25	10.50
	Positive Ranks	8[b]	5.56	44.50
	Ties	0[c]	-	-
	Total	10	-	-

a. POST < PRE
b. POST > PRE
c. POST = PRE

Test Statistics[a]	
	POST - PRE
Z	-1.741[b]
Sig. asymp. (bilateral)	0.082

a. Wilcoxon Signed-Rank Test
b. Based on negative ranks