*Ciência & Educação*, Bauru, v. 28, e22038, 2022
https://doi.org/10.1590/1516-731320220038

ARTIGO ORIGINAL

# An investigative study on teachers' level of expertise on the triad science-pedagogy-technology: evaluating Chemistry classrooms during the pandemic

# Estudo investigativo do domínio dos professores sobre a tríade do conteúdo científico, pedagógico e tecnológico: uma análise das aulas de Química durante a pandemia

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**Abstract**: During the pandemic, the required changeover to Emergency Remote Teaching presented various technological hurdles for instructors all around the world, as well as a fertile field of study dedicated to reshaping existing teaching methods into the manner in which education is delivered today. With an investigative slant, this study examines a group of students' perceptions on their professors' pedagogical practices, focusing on abilities and competencies related to Technological Pedagogical Content Knowledge (TPACK). To that purpose, 324 students evaluated their professors' ability to grasp the interrelated triangle of scientific, pedagogical, and technical material in their lessons. The Survey research technique was employed for a quantitative inquiry, then a statistical method of deductive imprint. When combined with the pedagogical aims and scientific contents of chemical science, the findings indicate a guiding need for teaching techniques and pedagogical reform for the development of technological skills.

**Keywords**: Chemistry teaching; Distance education; Technology in education; Teaching practice.

**Resumo**: A mudança para o Ensino Remoto Emergencial durante a pandemia trouxe consigo desafios tecnológicos para professores, e gerou um campo frutífero para pesquisas que discutam a remodelagem das práticas de ensino, além de investigações sobre os modos de como o ensino vem sendo ofertado. Este artigo descreve as percepções de um grupo de alunos sobre as práticas de seus professores na pandemia, enfatizando as habilidades e as competências em relação ao Conhecimento Tecnológico Pedagógico do Conteúdo (CTPC). Para tanto, 324 estudantes avaliaram como os seus professores dominavam a tríade relacional do conteúdo científico, pedagógico e tecnológico em suas aulas. Foi utilizada uma investigação quantitativa por meio da pesquisa Survey e a interpretação dos dados ocorreu pelo método estatístico de cunho dedutivo. Os resultados apontam para a necessidade orientadora das práticas docentes e aperfeiçoamento pedagógico para o desenvolvimento de habilidades tecnológicas quando integradas aos objetivos pedagógicos e aos conteúdos científicos da ciência química.

**Palavras-chave**: Ensino de química; Educação a distância; Conhecimentos tecnológicos; Prática docente.

*Received on: 28/1/2022*
*Approved on: 12/6/2022*

## Introduction

The COVID-19 pandemic has caused impactful changes in our lives and, above all, has directly influenced the modus operandi of education across the planet. To make matters worse, all this change happened in spite of the teachers' technological skills, thus showing weaknesses with regard to the use of technologies as pedagogical tools of scientific support for the development of teaching and learning processes. And, in an instant, everyone was challenged to use technology as the only way to continue the educational process, albeit in an emergency and, in many cases, without any institutional support. It is true that the importance of incorporating technologies with a pedagogical bias into the classroom has long been debated, and this discourse is accompanied by the defense of promoting initial and continuing training for teachers, in addition to equipment, maintenance, and internet access available at school. However, what is experienced is a kind of individualized continuing education headed by each teacher in an attempt to adapt themselves, adapt technologies, and adjust those technologies to their pedagogical specificities. All of this has had a direct impact on how to teach, as successful online learning requires students (and teachers) to be familiar and proficient in the use of these devices for learning (GARCÍA; WEISS, 2020).

However, while teachers needed to demonstrate supposed skills with technologies in the face of Emergency Remote Education (ERE) to promote the teaching of chemistry to their students, on the other hand, during the classes they experienced student apathy, realizing that their learning difficulties appear to be more accentuated, and the reasons can be diverse, such as a bad internet connection, a lack of proper equipment, i.e., notebook computers, absence of experimental classes, etc. It is well known in this bias that there are challenges for online teaching and learning processes for students, teachers, and higher education institutions, such as hardware, bandwidth and software issues (COMAN *et al*., 2020). It is undeniable that during the pandemic, both teachers and students were forced to adapt to the new scenario when attempting to implement palliatives to reduce the impact generated in the teaching and learning processes of chemical science. After all, even using palliatives to alleviate ERE difficulties, such as video lessons and simulations, these do not adequately replace practical learning in chemistry laboratories (SOARES *et al*., 2020), because experimental activities are essential in the scientific teaching and learning processes (BASSOLI, 2014).

Furthermore in addition to all of the Technological Educational Emergency Dependence (TEED) that put teachers in an awkward position in relation to their pedagogical praxis, as it demanded that they abandon "postures based on traditional teaching" (SILVA *et al*., 2020, p. 18), there are still barriers that appear almost insurmountable to teach chemistry as it truly requires, because it is a science with a high degree of abstraction, involving representations of a macroscopic, microscopic, and symbolic nature (TREAGUST, 2016). As a consequence, it is seen as a challenging field since it includes abstract concepts and has little relevance to students' daily lives (SIRHAN, 2007). After all, chemistry teachers were forced to adapt teaching practices to online environments that were strange to many of them (TALANQUER *et al*., 2020), as the coronavirus epidemic has wrought substantial change, offering several problems to the global higher education community (GONZALEZ *et al*., 2020).

Teachers, in particular, needed to plan a range of remote teaching tactics so that students may learn chemistry at home while having "fun" (SARI *et al*., 2020). This range of techniques is treated not just as technology-related concerns, but also as educational and scientific challenges. The way teacher teaches chemistry is based on theoretical and epistemological assumptions derived from everyday pedagogical activity, taking into account the didactic resources and instructional strategies available to reality itself (BEDIN, 2021). In other words, teachers must organize technical and pedagogical approaches to scientifically teaching objects of study of Chemistry. Thus, in addition to mastering a specific Digital Competence (DC) that includes the use of technological, informational, multimedia, or communication skills and knowledge teachers were suddenly required to relate the DC to the pedagogical methods of teaching and the scientific content to be developed (ESTEVE-MON; LLOPIS; ADELL-SEGURA, 2020).

In 2005, based on Shulman's (1986, 1987) notion of Pedagogical Content Knowledge (PCK), a conceptual framework was designed to integrate technology with a focus on improving teaching and learning processes. This structure became known as Pedagogical Technological Content Knowledge (TPACK) (KOEHLER; MISHRA, 2005). It is worth noting, however, that its role is to guide the teacher's knowledge (ENGIDA, 2014) in the face of the integration of three domains of knowledge during a given action, that is, Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK) (KOEHLER; MISHRA, 2008), and the intersections between these three basic sets of knowledge give rise to four other distinct domains, the central intersection being referred to as TPACK (RIBEIRO; PIEDADE, 2021).

Still, according to the creators of the structure, Koehler and Mishra (2009), obtaining TPACK is not the same as having separate knowledge of content, pedagogy and technology, respectively; consequently, in order to provide relevant and highly proficient teaching, each field of knowledge must be integrated simultaneously. Finally, TPACK advises teachers

> [...] about the pedagogical insertion of digital technologies in the classroom with a view to scientific content, rather than just their operation and handling, because it is the foundation of knowledge regarding the complex multimodal relationships between pedagogy, content and technology. (SILVA; SIQUEIRA; BEDIN, 2021, p. 141, our translation).

Furthermore, in order to bring improvements to the educational sector, teachers should understand that incorporating technology into their instruction must occur in any topic area (SCHMIDT *et al*., 2009).

However, DC demanded, on the part of teachers, the confident and critical use of Information and Communication Technologies (ICT) during the ERE adopted in Brazil. ERE is a "[...] teaching modality, adopted quickly in the most diverse institutions in the country, in order to maintain social distance, so that the school year is not lost, trying to minimize, in some way, the impacts on the students" (SILVA *et al*., 2020, p. 3, our translation). However, the concept of DC is connected to the formation of teachers' knowledge based on an integrative view of Technological Pedagogical Content Knowledge (TPACK). This is a combination of expertise that is essential for effective technology-assisted teaching (KOEHLER; MISHRA, 2009). However, it is vital that teacher education courses relinquish the existing emphasis on skills-based digital literacy in favor of wider DC models that reflect teachers' different knowledge, abilities, and contexts (FALLOON, 2020). In other words, instructors must be literate in order to assist young pupils in the development of skills and to enable the optimal deployment of ICT in the teaching process (MACHADO; BEDIN, 2020).

Therefore, the purpose of this study is to examine and statistically comprehend a group of students' perspectives on teaching approaches at these times, focusing on their abilities and competencies in relation to Pedagogical Knowledge of Content (PKC), Technological Knowledge of Content (TKC) and Technological Pedagogical Knowledge (TPK). Such research is significant because it is understood that the pre-COVID era introduced innovative and contemporary methods that established the "digital way of learning chemistry" (JENNIFER; LIPIN, 2020), but have Brazilian students been able to perceive, in view of the pedagogical practices offered during the pandemic, the efforts of their chemistry teachers in light of the contents above?

This article presents the findings of a scientific study conducted on the perceptions of chemistry undergraduates on the theoretical and practical domains of its teachers regarding the intersection of pedagogical knowledge, technological and scientific tools to teach chemistry during the pandemic. Such exposure is required because the triad that underpins the TPACK structure has played a significant role in rethinking teacher education curricula as well as current teacher education and technology practices around the world, owing primarily to the COVID-19 pandemic.

## Methodological design

The research reported here is of the Survey type and follows a quantitative methodological route with a deductive bias based on examination of statistical data, the sample of which was chosen for convenience (MCMILLAN; SHUMACHER, 2005). In this type of research "[...] the collection of information from a sample of individuals occurs through their answers to questions" (CHECK; SCHUTT, 2012, p. 160). About quantitative research, it "[...] only makes sense when there is a very well-defined problem and there is information and theory about the object of knowledge, understood here as the focus of the research and/or what one wants to study" (SILVA; LOPES; BRAGA JUNIOR, 2014, p. 3, our translation). Therefore, the choice for this framework for it understands the dimensions of the object of knowledge to be investigated, as well as its features, which allows for the construction of an attitude scale of the respondents based on the dimensions of the object (SILVA; LOPES; BRAGA JUNIOR, 2014).

In this sense, data was interpreted using the deductive approach, which "seeks explanations and probabilistic generalizations" (MORAES, 1999, p. 11, our translation), allowing, according to the author, "[...] achieve degrees of clarity, rigor and systematization more acceptable within the perspective of conventional research". The data was analyzed using the Software SPSS (Statistical Package for the Social Sciences), which allowed them to be interpreted quantitatively using descriptive statistics and the Kruskal-Wallis non-parametric test (KRUSKAL; WALLIS, 1952). The data were compiled via an online questionnaire distributed via Link to undergraduate chemistry students (bachelors and licentiates) from public educational institutions in Brazil. After completing the questionnaire, the data was saved in the cloud and then converted to a CSV (comma-separated values) format file.

The developed questionnaire (**chart 1**) was distributed for seven days and included, in addition to a section aimed at surveying the respondents' sociodemographic profile, nine statements aimed at raising, in the light of the students' declarative statements, their perceptions of teaching skills in relation to the correlation of scientific, pedagogical and technological knowledge. It should be mentioned that these assertions are based on a questionnaire that was in fact created and evaluated (CHAI *et al*., 2011; KOH; CHAI, 2014). Through it, we evaluate the seven knowledge bases that make up the TPACK framework using various assertions. Due to considerable testing of its features under factor and consistency analysis, including evidence of validity and reliability, the questionnaire with a focus on the Pedagogical Content, Technological Pedagogical, and Technological Content Knowledge Bases was chosen.

These statements were structured using a scale adapted from Likert's proposal (LIKERT, 1932), with four points emphasizing the degrees of agreement (4 and 5) and disagreement (1 and 2). It was chosen not to include a neutral midpoint on this scale in order to encourage responders to take a side (COLTON; COVERT, 2007).

However, in terms of the teaching context encountered by the participants in this study, it is stated that, as a result of the increase in infections caused by the SARS-COV-2 virus, which causes COVID-19, the Ministry of Education (MEC) approved Ordinance Nº 343, of March 17, 2020, allowing schools and universities to teach using digital media. (BRASIL, 2020). Thus, emergency remote learning (ERE) was accepted by public educational institutions. Classes have been developed to use the Google Meet conference platform, while commercial universities embraced the Distance Learning (EaD) model, which offers a Virtual Learning Environment (VLE). Therefore, it is clear that the educational experience of the research participants occurred entirely off-site. Students from public universities attended synchronous sessions given by professors at the same times and periods of on-site teaching, action described by the ERE, while students from private institutions, through the VLE, were monitored by their teachers in relation to scientific progress from an organization of actions and learning situations through monitoring resources, accessibility and pedagogical interventions. These activities may be influenced by the discipline's and classes' special qualities, as well as the technical circumstances of contact, information and communication.

## Results and discussion

We have the profile of the subjects based on the first portion of questions in the online form, where we tried to learn the gender, age range, course time, and location of Brazil from each one. In summary, 36.11% (n = 117) of the 324 undergraduate chemistry students are male, 62.97% (n = 204) are female, and 0.92% (n = 3) are 'other'. Still, 6.48% (n = 21) of this entire universe of students are under the age of 18, 62.35% (n = 202) are between the ages of 19 and 24, 18.52% (n = 60) are between the ages of 25 and 30, 6.18% (n = 20) are between the ages of 31 and 36, 3.70% (n = 12) are between the ages of 37 and 42, and 2.77% (n = 9) are 43 or older. Brazil's regions are as follows: 4.32% (n = 14) in the North, 54.01% (n = 175) in the South, 10.20% (n = 33) in the Midwest, 18.20% (n = 59) in the Northeast, and 13.27% (n = 43) in the Southeast. Still, in terms of Brazil's regions, which have continental dimensions, we consider that the heterogeneous group of subjects is made up of respondents from various federative units (totaling 27 states) that comprise each of the 5 regions, as well as different educational institutions in each state.

**Table 1** provides a detailed comparison of the information listed in the subject profile section, which allows one to estimate the number of students by geographic region of the nation while taking into account their age, gender, and graduation date. The largest group of respondents is from the South of the country (54.01%, n = 175), the age group with the largest group is between 19 and 24 years old (62.35%, n = 202), and the students who answered the questionnaire the most are at the beginning of their graduation, between the 1st and 2nd semesters (26.23%, n = 204). In short, it is possible to note that for each category there is a prominent group. Given that the questionnaire was sent uniformly to Higher Education Intuitions in the five regions of the country, it is notable that the southern area shown stronger adherence in regards to the number of responses. However, the adhesion of the participants did not occur uniformly since this process can be influenced by different factors, such as the mobilization of the course coordinators to send the questionnaire and the availability of the participants to answer the questionnaire, among others.

**Table 1** – Combination between the categories referring to the profile of the subjects

| Gender | Course Period | Age Range | Region of Brazil | | | | |
|---|---|---|---|---|---|---|---|
| | | | North | South | Midwest | Northeast | Southeast |
| Male | 1st or 2nd semester | Less than or equal to 18 years | 0 | 2 | 0 | 2 | 1 |
| | | Between 19 and 24 years | 1 | 13 | 1 | 8 | 1 |
| | | Between 25 and 30 years | 0 | 1 | 1 | 1 | 0 |
| | | Between 31 and 36 years | 0 | 1 | 0 | 0 | 0 |
| | | Between 37 and 42 years | 0 | 1 | 0 | 0 | 0 |
| | 3rd or 4th semester | Between 19 and 24 years | 1 | 6 | 1 | 1 | 3 |
| | | Between 25 and 30 years | 0 | 1 | 0 | 4 | 1 |
| | | Between 31 and 36 years | 0 | 0 | 0 | 1 | 0 |
| | | Greater than or equal to 43 years | 1 | 1 | 0 | 0 | 0 |
| | 5th or 6th semester | Between 19 and 24 years | 1 | 8 | 0 | 2 | 1 |
| | | Between 25 and 30 years | 0 | 4 | 0 | 1 | 0 |
| | | Between 31 and 36 years | 0 | 1 | 0 | 0 | 1 |
| | | Between 37 and 42 years | 0 | 0 | 0 | 3 | 0 |
| | 7th or 8th semester | Between 19 and 24 years | 0 | 4 | 2 | 4 | 1 |
| | | Between 25 and 30 years | 0 | 3 | 0 | 1 | 0 |
| | | Between 31 and 36 years | 0 | 1 | 1 | 0 | 1 |
| | | Between 37 and 42 years | 0 | 0 | 1 | 0 | 0 |
| | | Greater than or equal to 43 years | 0 | 0 | 1 | 1 | 0 |
| | 9th or 10th semester | Between 19 and 24 years | 0 | 2 | 4 | 0 | 2 |
| | | Between 25 and 30 years | 0 | 6 | 0 | 0 | 1 |
| | | Between 31 and 36 years | 0 | 1 | 0 | 1 | 1 |
| | | Greater than or equal to 43 years | 0 | 1 | 0 | 0 | 0 |
| Female | 5th or 6th semester | Between 19 and 24 years | 2 | 17 | 5 | 4 | 6 |
| | | Between 25 and 30 years | 0 | 9 | 1 | 4 | 0 |
| | | Between 31 and 36 years | 0 | 0 | 0 | 0 | 1 |
| | | Greater than or equal to 43 years | 0 | 1 | 0 | 0 | 0 |
| | 7th or 8th semester | Between 19 and 24 years | 2 | 11 | 2 | 5 | 3 |
| | | Between 25 and 30 years | 1 | 5 | 0 | 5 | 0 |
| | | Between 31 and 36 years | 0 | 4 | 0 | 0 | 0 |
| | 9th or 10th semester | Between 19 and 24 years | 1 | 7 | 1 | 0 | 2 |
| | | Between 25 and 30 years | 0 | 2 | 1 | 0 | 1 |
| | | Between 37 and 42 years | 0 | 0 | 0 | 0 | 1 |
| | | Greater than or equal to 43 years | 0 | 2 | 0 | 0 | 0 |
| Other | 1st or 2nd semester | Less than or equal to 18 years | 0 | 1 | 0 | 0 | 0 |
| | | Between 19 and 24 years | 0 | 1 | 0 | 0 | 0 |
| | 5th or 6th semester | Between 37 and 42 years | 0 | 0 | 1 | 0 | 0 |

Source: Prepared by the authors.

Following the section on the subject profiles, the online form included an evaluation section on the teaching action, with 9 statements were made available, three of which emphasized the Pedagogical Knowledge of the Content (PKC), three addressed the Pedagogical Technological Knowledge (PTK) and three demarcated Technological Content Knowledge (TCK). Following the degree of agreement indicated by the participants, a descriptive analysis was performed on the claims using the SPSS program, from which the lowest and maximum degrees, as well as the mean and standard deviation, were produced. The statement is detailed in **chart 1**, which also includes the abbreviation used for each statement.

**Chart 1** – Descriptive analysis on the statements available

| | Acronyms | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|---|
| **Group 1: PKC - Pedagogical Knowledge of the Content** | | | | | |
| My teacher was able to deal with the most common conceptual errors I had. | PKC1 | 1 | 4 | 2,94 | 0,874 |
| My teacher approached different teaching strategies to guide me to think and learn chemistry. | PKC2 | 1 | 4 | 2,71 | 0,994 |
| My teacher was able, in different ways, to help me understand chemical knowledge. | PKC3 | 1 | 4 | 2,94 | 0,906 |
| **Group 2: PTK – Pedagogical Technological Knowledge** | | | | | |
| My teacher was able to use technology to insert me into real-world situations. | PTK1 | 1 | 4 | 2,53 | 0,990 |
| My teacher helped me to use technology to find more information, plan and monitor my learning. | PTK2 | 1 | 4 | 2,45 | 1,002 |
| My teacher helped me to use technology to build different forms of knowledge representation and to work collaboratively. | PTK3 | 1 | 4 | 2,47 | 0,981 |
| **Group 3: TCK – Technological Content Knowledge** | | | | | |
| My teacher was able to use software created for chemistry in his classes. | TCK1 | 1 | 4 | 2,42 | 0,997 |
| My teacher demonstrated how to use technology to research chemistry. | TCK2 | 1 | 4 | 2,95 | 0,914 |
| My teacher used different technologies to represent the chemistry content in his classes. | TCK3 | 1 | 4 | 2,55 | 0,964 |

Source: Prepared by the authors.

It can be seen in **chart 1** that the averages for each statement within the knowledge groups fall starting with the PKC, then move through the TCK, and ultimately reach the PTK. In this sense, it is clear that there is more agreement with the statements that discuss content than with the claims that discuss pedagogy and technology. Nevertheless, it should be highlighted that, when evaluated through the mean, all claims, regardless of the knowledge group, earning a minimum degree of 1 and a maximum degree of 4, fall inside the degree of agreement. After all, a variation of agreement on the 4-point Likert scale shows an average of indifference at point 2, and all the assertions have an average that is greater than this figure.

In particular to Group 1, referring to the PKC, it is notorious that it has the highest averages in its statements, plotting an overall average of 2.86. In addition, it is evident in this group that the assertions PKC1 and PKC3 present the same mean (M = 2.94), but different standard deviations, SD = 0.874 and SD = 0.906, respectively. Therefore, by the standard deviation of each mean, it can be understood that there was a significant dispersion of notes in the degrees of agreement for the statement PKC3. As a result, it is clear that there is higher agreement about the notion that the teacher was able to deal with the most frequent conceptual mistakes that their students had, followed by the notion that the teacher was able, in many ways, to assist his students in their grasp of chemical knowledge, as well as approach numerous teaching tactics to encourage their students to think and study chemistry.

In this perspective, Group 1 of knowledge brings assertions that enable the student to carry out an assessment of teaching skills in relation to the articulation of pedagogical knowledge with content knowledge. As a result, it's understandable that the students agreed with the statements, because pedagogical content knowledge is an instructive pedagogical method for teachers to plan, organize and present scientific content to students. The PKC addresses teaching knowledge in connection to the activity of teaching material, boosting student learning, through non-specific teaching techniques and approaches (SEUFERT *et al*., 2016). Thus, it is known that little or practically nothing has changed in distant teaching activities, gaining agreement of the subjects in connection to the statements, in reference to the didactic approach for the teacher to present content, as well as their scientific mastery over it.

Group 2, which refers to the knowledge that connects technology and pedagogy, had lower averages of agreement than the other knowledge groups, with an overall mean of 2.48. However, based on the individual average of each statement, it is possible to see a greater agreement of the subjects in relation to the idea that the teacher was able to use technology to insert subjects in real-world situations. Besides that, this was followed by the idea that the instructor assisted students in using technology to construct various types of knowledge representation and collaborate, as well as in using technology to acquire more information, plan and monitor their own learning.

Pedagogical Technological Knowledge, addressed in the statements of Group 2, presents the integration between technological knowledge and the pedagogical knowledge of the teacher; it is a knowledge in which scientific knowledge is not considered, but how technology can interfere in the pedagogical strategy and vice versa. PTK is a teaching knowledge capable of understanding the limitations and ease of the relationship of technology with the pedagogical context (COX, 2008); it is a knowledge in which the teacher perceives how rich and significant the use of a certain technology is in improving his educational practice, independent of the content. Thus, it is realized that, while this information was likely the most important throughout the ERE process, it was not available in the teacher's intradisciplinary didactic repertoire, resulting in no student agreement with the statements.

Finally, on Group 3, the participants agree with the statements, with an average mean of 2.64. There is a preference in the subjects’ agreement in this drawing, as well as in the other knowledge groups, which is reflected in the concept that the teacher demonstrated how to use technology to research about chemistry, followed by the concept that the teacher has used different technologies to represent the chemistry content in the classroom, as well. Concerning this, the mean is considered low for this group of knowledge in relation to assertive 1 (TCK, M = 2.42), since this presents a conception that the teacher used different technological tools in the classroom, which denotes pedagogical knowledge, similar to that listed in Group 2 of knowledge.

The Group 3 knowledge statements bring concepts to the subjects in order to assess the teacher's content knowledge connected to their technological knowledge; that is, the TCK is a specific knowledge of the teacher where technologies and scientific knowledge are reciprocally related; it is through this knowledge that the teacher establishes and determines, without a pedagogical link, which technology can be used to develop a given scientific content. It is critical for the educator to be able to link scientific knowledge to technology in such a way that both complement one another (COX, 2008). In this sense, it is an action that requires much more than just tinkering with technology, but knowing how to select it to present specific content. Given that the chemistry subject has special technical characteristics and that remote teaching requires teachers to have certain abilities and attitudes towards technology, it is clear from this line that the students agree with the statements. which favors the pedagogical skills in connection to this process.

Due to the lack of normality in the data distribution, it was chosen to evaluate these statements using the Kruskal-Wallis non-parametric test, to the detriment of the descriptive analysis done for each of the statements contained in the three knowledge groups. This test was conducted utilizing legacy dialog boxes and the categorical factors listed in **table 1**, being: Gender (**table 2**), Age range (**table 3**), Region of Brazil (**table 4**) and Course Period (**table 5**). Analysis using this method was possible because each category has at least 3 subcategories. In addition, the analysis was run with a p value less than 0.05 considered significant (p 0.05) to reject the null hypothesis, assuming that there is category interference in the data distribution. If the p-value in any given analysis is larger than 0.05 ($p > 0.05$), the null hypothesis is kept, provided that there is no statistical interference by the category in the assertion.

**Table 2** – Analysis of the Kruskal-Wallis's test for the Gender category

| | PKC1 | PKC2 | PKC3 | PTK1 | PTK2 | PTK3 | TCK1 | TCK2 | TCK3 |
|---|---|---|---|---|---|---|---|---|---|
| Chi-Square | 1,441 | 0,031 | 1,538 | 3,162 | 0,210 | 0,748 | 0,219 | 0,669 | 0,980 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | 0,486 | 0,985 | 0,464 | 0,206 | 0,900 | 0,688 | 0,896 | 0,716 | 0,613 |

Source: Prepared by the authors.

**Table 3** – Analysis of the Kruskal-Wallis's test for the Age Range category

| | PKC1 | PKC2 | PKC3 | PTK1 | PTK2 | PTK3 | TCK1 | TCK2 | TCK3 |
|---|---|---|---|---|---|---|---|---|---|
| Chi-Square | 3,971 | 6,153 | 4,587 | 7,877 | 9,202 | 11,278 | 12,354 | 9,923 | 7,104 |
| df | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Asymp. Sig. | 0,554 | 0,292 | 0,468 | 0,163 | 0,101 | 0,046 | 0,030 | 0,077 | 0,213 |

Source: Prepared by the authors.

**Table 4** – Analysis of the Kruskal-Wallis's test for the Region of Brazil category

| | PKC1 | PKC2 | PKC3 | PTK1 | PTK2 | PTK3 | TCK1 | TCK2 | TCK3 |
|---|---|---|---|---|---|---|---|---|---|
| Chi-Square | 5,340 | 4,099 | 2,326 | 3,058 | 3,460 | 5,364 | 4,283 | 3,552 | 2,070 |
| df | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Asymp. Sig. | 0,254 | 0,393 | 0,676 | 0,548 | 0,484 | 0,252 | 0,369 | 0,470 | 0,723 |

Source: Prepared by the authors.

**Table 5** – Analysis of the Kruskal-Wallis's test for the Course Period category

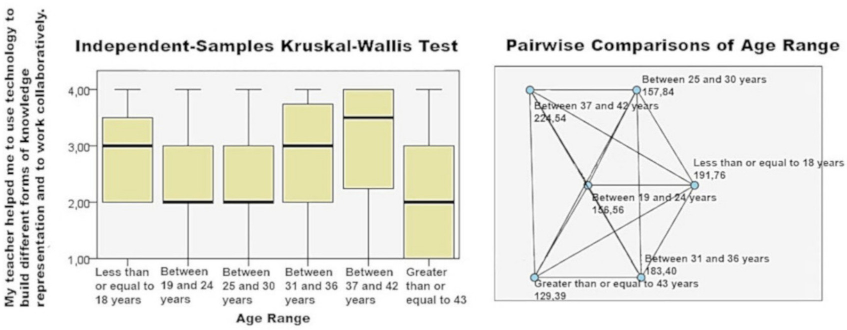
| | PKC1 | PKC2 | PKC3 | PTK1 | PTK2 | PTK3 | TCK1 | TCK2 | TCK3 |
|---|---|---|---|---|---|---|---|---|---|
| Chi-Square | 3,891 | 8,452 | 8,146 | 17,583 | 12,929 | 17,324 | 1,846 | 3,498 | 10,335 |
| df | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Asymp. Sig. | 0,421 | 0,076 | 0,086 | 0,001 | 0,012 | 0,002 | 0,764 | 0,478 | 0,035 |

Source: Prepared by the authors.

Taking a look at the data in tables 2, 3, 4, and 5, it is possible to see in the last line of each table, characterizing the degree of significance (p 0,05), that only for some assertions in the Age Range and Course Period categories is a p with a value less than 0.05 found. As a result, it is reasonable to conclude that because all assertive in the categories Gender and Region of Brazil have $p > 0.05$, statistically, the null hypothesis must be maintained, and thus these categories have no influence on the assertive. However, within the Age Group category, a $p < 0.05$ is identified for the statement PTK3, within Group 2 of knowledge, and for the statement TCK1, within Group 3 of knowledge. Thus, in these cases, one must reject the null hypothesis and admit, statistically, that there is interference by the category in these assertions.

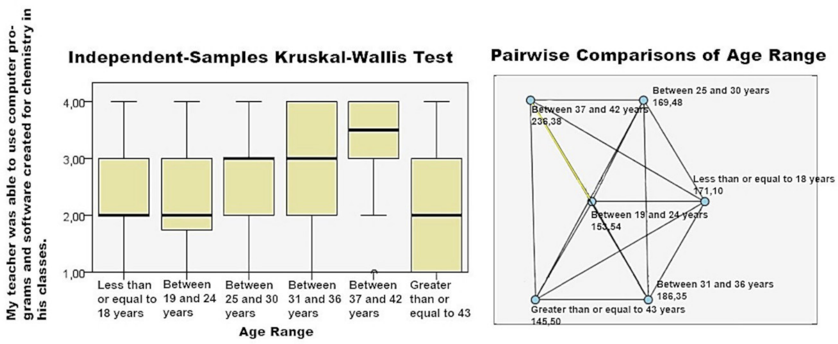
Corroborating, p values less than 0.05 can be found in the Course Period category for the three statements in Group 2 of knowledge (PTK1, PTK2, PTK3) and the last statement (TCK3) in Group 3 of knowledge. Thus, as previously stated, the null hypothesis is rejected and the alternative hypothesis is retained, assuming that, statistically, there is no statistical normality in the distribution of data in these statements. In light of the foregoing, a detailed statistical analysis was performed in pairs to determine which subcategories, within the Age Group and Course Period categories, displayed significantly non-normality in the data distribution, identifying the one shown in **figure 1** and **figure 2** for the statements PTK3 and TCK1 within the Age Range category. The pairwise comparison was carried out using the Kruskal-Wallis's test of independent samples, rather than legacy dialog boxes, as previously, customizing the tests in the form of a pair.

**Figure 1** – Pair analysis of the PTK3 assertion




Source: Prepared by the authors.

**Figure 2** – Pair analysis of the TCK1 assertion



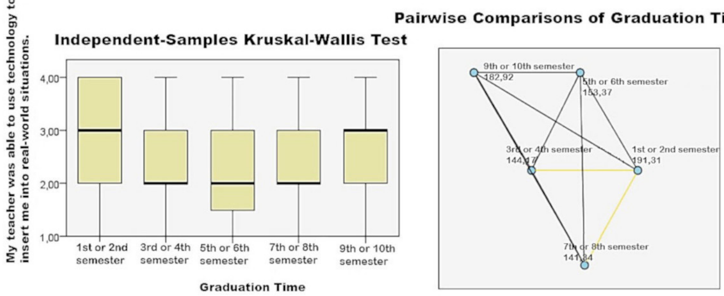

Source: Prepared by the authors.

Regarding what is depicted in **figure 1**, it is clear that after performing the Kruskal-Wallis's test of independent samples, exclusively for the assertion PTK3, revealed that there is no statistically significant effect of subjects of any age range on the claim, as noted in **table 3**, where it is evident that there is interference [$X^2$ (5) = 12,354; $p < 0,05$]. According to this design, the Kruskal-Wallis's test of independent samples was recalculated with the value of p being a value extremely near to the value to reject the null hypothesis, with no abnormality in the distribution of data in this category for PTK3. However, unlike what happened with the assertive PTK3, it can be observed in **figure 2**, where the idea of teachers being able to employ chemical software in their lectures is kept, that the only statistically significant difference is between the subjects aged 19 to 24 and subjects aged 37 to 42. In this diagram, based on the data in **table 3**, it can be stated that the Kruskal-Wallis's test revealed that there is an influence of Age Range on the assertion TCK1 [$X^2$ (5) = 11,278; $p < 0,05$].

In short, the Age Range category has an influence on the claim that addresses the notion of the instructor employing software in the classroom, signaling the linkage of technical and scientific knowledge, according to the Kruskal-Wallis's test of independent samples. Thus, it is hypothesized that the difference in data distribution arises because the group of subjects aged 19 to 24 years, as shown in **table 1**, is arranged in all graduating periods, as opposed to the group of subjects aged 37 to 42 years, which is only in the early periods of graduation. That is, there may be a disagreement of the group of subjects with a lower age in relation to the assertion because, perhaps, this one expected that the professors, due to the length of experience and due to their knowledge of chemical science, could present various programs and science specific software. Carlini (2008), on the other hand, warns that higher education teachers are attached to the presential tradition of knowledge transmission; thus, the introduction of technologies in the academic environment necessitates a continuous need to adapt the teaching activity, which may not occur during the teaching of chemistry.

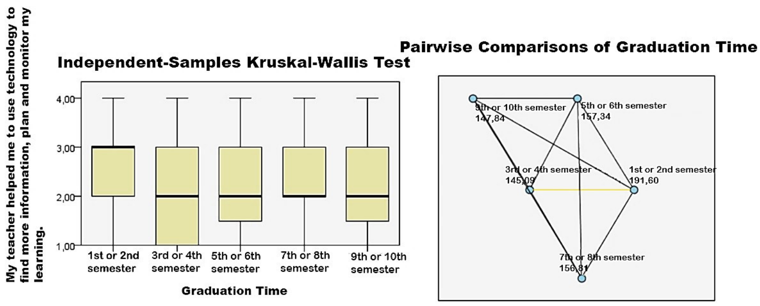
As a result of the above, the figures 3, 4, 5 and 6 show the Kruskal-Wallis's test of independent samples for assertions PTK1, PTK2, PTK3 and TCK3 in the Course Period category.

**Figure 3** – Pair analysis of the PTK1 assertion



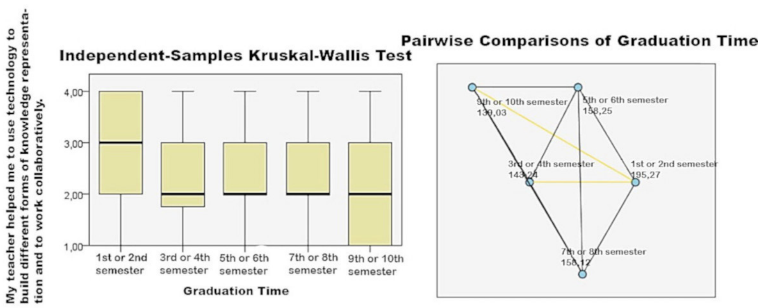

Source: Prepared by the authors.

**Figure 4** – Pair analysis of the PTK2 assertion



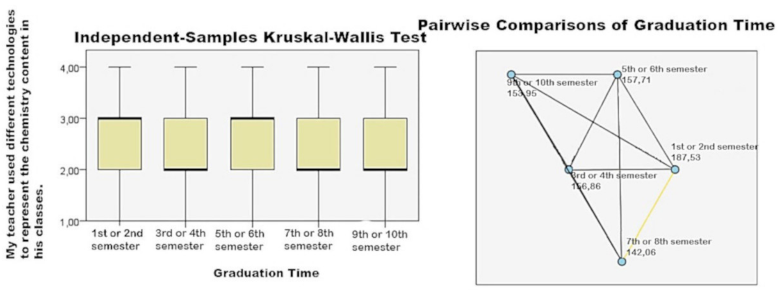

Source: Prepared by the authors.

**Figure 5** – Pair analysis of the PTK3 assertion




Source: Prepared by the authors.

**Figure 6** – Pair analysis of the TCK3 assertion




Source: Prepared by the authors.

Given what is shown in **figure 3**, it is clear that there are two statistically significant differences about the assertion: *My teacher was able to use technology to insert me in real-world situations*, in relation to the subjects' course period. In summary, students between the first and second semesters differ from those between the third and fourth semesters, as well as those between the seventh and eighth semesters. Thus, through the data in **table 5**, it is understood that the Kruskal-Wallis's test reveals that there is an effect of Course Period on the assertion PTK1 [$X^2$ (4) = 17,583; $p < 0,05$]. Similarly, for the PTK2 claim, as shown in **figure 4**, there is a statistically significant difference between participants in their first and second semesters of graduation and those in their third or fourth semester [$X^2$ (4) = 12,929; $p < 0,05$].

Based on the aforementioned and **chart 1**, it is clear that the assertions PTK1 and PTK2 address the teaching skills in relation to the integration of technological knowledge with pedagogical knowledge, primarily with an emphasis on the action of placing students in real-world situations and monitoring their learning. As a result, there is a statistically significant difference in the data between students in the first and second semesters of graduation and those in the third and fourth semesters, as well as those in the seventh and eighth semesters of graduation. Perhaps, this difference occurs because students who are at the beginning of graduation expect a more specific and directed action from the teacher, capable of making them scientifically understand chemistry in its context via a technological-pedagogical methodology, or because they expect more attention and empathy from the teacher, which rarely occurs. After all, development of tight and pleasant ties between the teacher and the students leads to the academic improvement of the subjects (ROORDA *et al*., 2017).

Also in relation to Group 2 of knowledge, referring to the PTK3 assertion, which emphasizes the idea of the teacher helping the subject to use technology to build different ways of representing knowledge and to work collaboratively, the non-parametric Kruskal-Wallis test revealed a statistically significant difference between in their first and second semesters of graduation and those present in the third or fourth semesters, as well as those nearing the end of their course (between the 9$^{th}$ and 10$^{th}$ semesters). Thus, through the data in **table 5**, it can be understood that there is an effect of the subjects' course period with the assertion PTK3 [$X^2$ (4) = 17,324; $p$ < 0,05]. Furthermore, based on the last statement from Group 3 on knowledge, which reflects on the teacher's ability to use different technologies to represent the chemistry content during their classes, it can be deduced from **table 5** that the Kruskal-Wallis's test validated that the Course Period of the subjects, particularly those in the first and second semesters, has an effect on the assertion TCK3 [$X^2$ (4) = 10,335; $p$ < 0,05].

When contrasted to the statements PTK3 and TCK3 of the subjects who are concluding the course, it is clear from the aforementioned claims that the group of students who are starting their graduation differs greatly from those closer to graduation (students of the 7$^{th}$, 8$^{th}$, 9$^{th}$ and 10$^{th}$ semesters). This is suggested in this hypothetical picture because the sentences highlight the teacher's use of technology to generate multiple types of representation, transmit chemical knowledge, and inspire pupils to collaborate. That is, it is possible to measure that the group of students who are at the start of graduation, having decided to do so, had already explored and even employed technological tools to grasp the scientific content of chemical science, waiting for the teacher to do the same, or possibly taking advantage of multiple distinct technological materials or program activities in which subjects could share ideas to learn collaboratively.

However, it is believed that such actions did not occur, since the activities in the remote period happened suddenly, and many teachers felt powerless with the disjointed fact of inserting technologies in their teaching praxis. After all, changing the setting so abruptly is not an easy effort, especially when it is necessary to research the content and pedagogical aspects of a specific content, plan, organize and teach classes using technological programs to represent the content in a collaborative manner. Furthermore, it is considered that students who are finishing the course did not care about the dynamics offered by their professors about technology, either due to a lack of particular knowledge or a lack of effort to integrate it in the classroom and accomplish educational goals, because they already have information about the teacher's abilities, as well as having undergone a considerable time of face-to-face experience on the facts and phenomena of chemical science (DECOITO; RICHARDSON, 2018).

Finally, it is thought that this pandemic-related issue can be viewed as a chance to reconstruct various long-standing educational institutions and establish better and more modern academic methods that are appropriate for the current generation of students (STRIELKOWSKI, 2020). This design is crucial because, as statistical analysis above demonstrates, students who are just starting their graduation display notable disagreements with other undergraduates, particularly when it comes to the technological and pedagogical knowledge of the teachers' content.

## Concluding remarks

As with the rest of the report, it is considered that this work highlights the urgency with which teaching methods and didactic updating must be related to the process of acquiring technology abilities when combined with the pedagogical objectives. Taking that into account, it sought to comprehend a group of students' perceptions of teaching techniques used during the pandemic, focusing on their abilities and competences in regard to the PKC, TCK, and PTK. Therefore, an orientation in chemistry teacher training is indicated so that teaching practices are linked to the development of technological competences added to the scientific contents of this science. Furthermore, it is important to note that, although the text is based on a statistical study of a group of students' perspectives, teaching practice is a complex and unique didactic action for each teacher, which makes it difficult to analyze and interpret.

However, statistical analysis of the data shows that, according to the Kruskal-Wallis nonparametric test, there was a need to reject the null hypothesis for the assertion PTK3, which belongs to Group 2 of knowledge and emphasizes the use of technology in a pedagogical way, for both the Age Group category and the Course Period category. In relation to knowledge Group 2, the null hypothesis was rejected for all assertions within the Course Period category, always to the detriment of students who are in the first and second semester of graduation, then those in the third and fourth semesters (PTK1, PTK2, PTK3), seventh and eighth semesters (PTK1), and those in the ninth and tenth semesters (PTK3). In this contribution, it is important to note that the subjects who demonstrate a significant difference in regard to the statements that strengthen the link of teachers' technical and pedagogical skills, as shown in **table 1**, are present in the three gender options, in the five regions of the nation, and have ages ranging from less than or equal to 18 years to greater than or equal to 43 years.

Nonetheless, it is believed that future research with this bias can be developed with the same group of subjects, as it is understood that the pandemic surprised everyone, particularly in the field of education. Also, the integration of technologies in the school context and in pedagogical practices and teachers' content is dependent on many factors, including the planning and organization of proposals and didactic strategies, attitudes, skills, abilities, infrastructure and tools, as well as the nexus between technological, pedagogical and scientific knowledge. Thus, it is hoped that this study will serve as a resource for teachers to better understand how their pedagogical methods contribute to the formation of subjects, as well as to assess students' perspective on the convergence of the triad science-pedagogy-technology.

Furthermore, in a public policy framework, it is thought that the continuation of research connected to TPACK may drive the improvement and maturity of novel practices in initial teacher education by integrating relevant implications for future research as well as enhancing theory and practice. Otherwise, this research suggests that undergraduate courses should update and organize their curricula in light of this theoretical model, either through a Training Program that aggregates multiple technological teaching tools, or through specific disciplines that focus on the practice of TPACK beyond the theoretical issue. Thus, significant, complementary and comparative elements will be found not only related to change in teacher education, but, more importantly, in the educational process of Basic Education students, primarily addressing the construction, organization and interconnection of scientific, pedagogical and technological knowledge.

Although it is well known that instruments based on the Likert scale contribute significantly  to studies involving the TPACK theoretical model, as they allow for broader discussions on the challenge of its implementation in the classroom, it should be noted that the results described here may have limitations capable of influencing the interpretation of the findings, as only the deductive method was used to provide explanations and probabilistic generalizations given the investigated sample. The use of a single methodology is thought to have constrained the research findings in this direction, as the inclusion of quantitative and qualitative methods would provide associations of and in the questionnaire, encouraging a mixed descriptive and reflective analysis on the assertions divided into three groups (PCK, PTK, TCK), considerably increasing the participants' ability to achieving communication objectives.

The screening research using the TPACK presented here is critical for future educational quality improvement since it is a pervasive problem in many countries, particularly in light of the COVID-19 pandemic. The findings about the TPACK framework, which was used as a theoretical model, are interesting because they envisage the development of skills and technological competences that are pedagogically integrated into the creation of specific content, which creates a space for discussion and perception of the urgent need for direction in teacher education. Therefore, it is strongly advised to support initiatives that are directed toward more research, with the goal of assisting teachers in using practical strategies for teaching chemistry while employing the TPACK model in a structured manner.

## Acknowledgements

Author 1 gratefully acknowledges the research support provided by Public Notices nº 137/2018 and nº 105/2020 of the Dean of Research and Graduate Studies (PRPPG) from the Universidade Federal da Integração Latino-Americana (UNILA).

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**ERRATA**

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Maria das Graças Cleophas

Everton Bedin"

**Leia-se**:

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Everton Bedin

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*Ciência & Educação*, Bauru, v. 28, e22038, p. 18, 2022.