The impact of COVID-19 on Brazilian teachers' perception of technology using Technological Pedagogical Content Knowledge (TPACK)

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ABSTRACT

Maintaining educational activities during the coronavirus pandemic has posed challenges to teachers as communication technologies are one such challenge. In this context, this study aimed to identify the consequences of intense exposure to digital technologies in pedagogical actions during the pandemic, outlining a profile of Brazilian teachers concerning the educational use of these technologies and applying the TPACK.xs questions. The methodological procedure was separated into two steps: (i) Survey Design and Data Collection and (ii) Data and Content Analysis. The 564 Brazilian teachers' results showed Brazilian teachers' position relative to TPACK. One of the impacts of using digital technologies adapted to educational processes was seen by 57% of Brazilian teachers who were positioned in technology-hybrid components. This study shows a possible turning point in teaching and learning processes, considering integrating pedagogy, content, and emerging technologies to face more accessible education. **Keywords:** Emerging technologies, TPACK, COVID-19, Integration of digital resources, digital technologies.

O impacto da COVID-19 na percepção de tecnologia dos professores brasileiros usando Conhecimento Tecnológico Pedagógico de Conteúdo (TPACK)

RESUMO

A manutenção das atividades educativas durante a pandemia do coronavírus tem apresentado muitos desafios aos professores, entre estes se destacam as tecnologias de comunicação. Nesse contexto, este estudo teve como objetivo identificar as consequências da intensa exposição às tecnologias digitais nas ações pedagógicas durante a pandemia, traçando um perfil dos professores brasileiros quanto ao uso educacional dessas tecnologias, aplicando as questões TPACK.xs. O procedimento metodológico foi separado nas etapas: (i) Desenho da Pesquisa e Coleta de Dados, e (ii) Dados e Análise de Conteúdo. A análise das respostas de 564 professores brasileiros mostraram a posição destes em relação ao TPACK. Os impactos do uso de tecnologias digitais adaptadas aos processos educacionais foi percebido por 57% dos professores brasileiros que se posicionaram em componentes híbridos de tecnologia. Este estudo mostra uma possível modificação nos processos de ensino e aprendizagem, integrarando pedagogia, conteúdo e tecnologias emergentes para enfrentar uma educação mais acessível. **Palavras-chave:** Tecnologias emergentes, TPACK, COVID-19, recursos digitais, tecnologias digitais.

1. Introduction

With the emergence of the COVID-19 pandemic, declared by the World Health Organization (WHO) (WORLD HEALTH ORGANIZATION, 2020), economic and professional activities have proceeded through digital tools. Similarly, education professionals have sought alternatives to continue academic activities through information and communication technologies (ICTs) (SAILER; MURBÖCK; FISCHER, 2021).The discussion around computational tools in the school curriculum is not recent, regardless of the pandemic. Studies on education technology discussed teachers' perceptions of processes involving adopting technologies (KIMM *et al.*, 2020).

Thus, several models and theories focused on educational technology proposed explaining and guiding movements in education at different levels and showing how ICTs reshape educational processes. Technological Pedagogical Content Knowledge (TPACK) is one such model. TPACK emphasizes how ICTs can be used in the classroom to transform and enhance teaching and learning (KOEHLER; MISHRA, 2006; WANG, 2022), seeking to identify the nature of knowledge required of teachers to integrate technology into their teaching practices. The framework illustrates teachers' understanding of technology, pedagogy, and content interactions when planning lessons. According to the TPACK authors, part of the problem is the tendency to look at ICTs without a broader discussion of their integration into educational processes. Mishra and Koehler (2006) stressed that the literature includes abundant examples of the use of technological tools without deeper empirical research on their actual effects.

Even with the development of models such as TPACK (SCHMID; BRIANZA; PETKO, 2020, 2021), which addresses the relationship between ICTs and learning, the pandemic has intensified teachers' exposure to digital technologies, urging for their immediate use. Thus, understanding how teachers associate content, pedagogy, and technology in educational processes contributes to the topic, showing a snapshot of the current scenario that allows inferences about the post-pandemic future. “Technology" refers to ICTs and their various computational tools and media in education (SHENOY; MAHENDRA; VIJAY, 2020). TPACK covers three fundamental knowledge components, namely pedagogical (PK), content (CK), and technological (TC). It also covers the three first-level hybrid components formed at their intersections: pedagogical content (PCK), technological pedagogical (TPK), and technological content (TCK). These components combine and generate the second-level hybrid knowledge component: technological pedagogical content (TPCK). The most complex type of knowledge relies on a creative combination and alignment of all knowledge domains mentioned above (SCHMID; BRIANZA; PETKO, 2021). An updated version of TPACK included contextual knowledge, which refers to awareness of available technologies in schools and the policies that guide technology integration within specific educational environments (MISHRA, 2019). Another update proposed a reduced instrument to measure all seven components of TPACK. They administered an initial questionnaire of 42 items to 117 high-school teachers in training. They used reliability analysis and confirmatory factor analysis to reduce the number of items per subscale and fit the model, which resulted in the final TPACK.xs questionnaire, consisting of 28 items grouped into seven constructs. The shortened instrument facilitates the integration of TPACK into large-scale studies and reduces the risk of respondent fatigue while providing sufficient accuracy.

This study aimed to identify the consequences of teachers' intense exposure to digital technologies in pedagogical actions during the pandemic, outlining a profile of Brazilian teachers concerning the educational use of these technologies, applying the TPACK.xs questions (SCHMID; BRIANZA; PETKO, 2020) to investigate technological, pedagogical, and content aspects based on descriptive and inferential statistics. The study surveyed elementary, high school, technical, undergraduate, and graduate professionals. The adoption of the TPACK.xs considers the seven knowledge domains in a few questions and complements it with questions addressing Brazilian teachers' educational background, performance, and personal traits. Theoretical contributions of this study involve the adaptation of TPACK.xs, especially regarding its use with a quantitative scale for variables, allows a deeper investigation into the answers' dispersion and variability, potentially improving the results of TPACK.xs. In practical terms, the results present a profile of Brazilian teachers and show how intense exposure to ICTs might affect pedagogical, technological, and content-creation processes. Furthermore, by

understanding the use of ICTs in pedagogical proposals, identifying mediating technological tools adopted during the pandemic might remain a post-pandemic educational legacy.

2. Methodology

The study design and the research method sought to produce knowledge applied to education using ICTs. This research used the mixed (qualitative-quantitative) method. The framework structure has two steps: (i) Survey Design and Data Collection, and (ii) Data and Content Analysis.

2.1. Survey Design and Data Collection

Based on the TPACK.xs variables, the data collection instrument helps identify the pedagogical practices adopted concerning digital technologies. The instrument mainly consisted of 28 items adapted from TPACK.xs, preceded by an investigation of the respondent's professional profile and followed by a demographic inquiry (e.g., age, gender, and academic background, as per the classification of the Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES, 2020)).

The collection instrument adapted the original qualitative scale to continuous quantitative analysis. This adaptation enabled a deeper investigation and allowed us to observe the relationship of TPACK.xs with other metrics. The original study also indicated limitations regarding sample size, applied to 117 respondents and a high school as the only target group. This study increased the sample by around 382% (564 respondents) and expanded the public to include others levels of education (except pre-school/pre-literacy). The data collection, approved by the ethics committee of the Federal Institute of Education, Science, and Technology of Rio Grande do Sul (CAAE 37218020.1.0000.8024), observed teachers with different academic backgrounds.

The target group represents the population affected at the moment or in the near future. Thus, the population consisted of teachers working in the Brazilian public and private school system. The sample size necessary to achieve $1-\propto= 0{,}95\%$ confidence and $\varepsilon = 5\%$ maximum error, estimated at 371 respondents, totalized 564 teachers of the estimated population of over 2.5 million teachers (INEP, 2018). The data collection occurred between November and December 2020.

2.2. Data and Content Analysis

The data collection occurs digitally in an open-source app developed specifically for this purpose (https://bit.ly/3wyDrqP). The link for completion, followed by a description of survey objectives, was shared on social media platforms (LinkedIn®, Facebook®, and WhatsApp®), beyond the sent e-mails to public and private schools around Brazil. Cronbach's alpha assessed the consistency of the questionnaire. Data analysis followed three steps. They first characterized respondents through a descriptive analysis. Second, a profile of respondents, built through an analysis of the observations of TPACK based on Principal Component Analysis (PCA) and Generalized Linear Model. Third, they analyze the impact of ICTs during the pandemic and their legacy.

The *characterization of respondents*, presented in frequency tables, aimed to describe the academic background, work, and individual characteristics of Brazilian teachers. The variables considered were gender, age, region of residence, the field of study, year of highest academic qualification, and the number of educational levels they taught simultaneously. The results discussion used Brazilian grey literature and official demographic studies. The next step is to identify the *profile associated with the TPACK.xs constructs* and analyze answers, the variables were observed into seven constructs composed of four variables, by PCA and GLM. The results were initially presented for each variable, describing the average behavior and variability of the scores assigned by

respondents to each question, while PCA verified the structural behavior of the constructs proposed by TPACK.xs. After identifying that structure, seven other PCAs (one for each construct) generated a single vector obtained (Equation 1).

$$Ranking = (\sum_{i=1}^{n} \text{score fatorial x standard variable}) x\ \lambda \quad (1)$$

where λ is the percentage of explained variance.

This study used GLM to identify the profile of teachers concerning each TPACK construct. Each of the seven vectors in the ranking was considered a response variable and variables profile as independent (p-value<0.05). Only characteristics with the most significant positive contribution were considered to establish a profile. In the final step, the *context of ICTs*, content analysis performed the open-ended qualitative response, which reported teachers' descriptions. The qualitative content coding resulted in a word cloud and critically analyzed respondents' statements. The open-ended response was not mandatory, but around 22% of respondents participated. The results from this stage grounded inferential discussions related to the educational practices of TPACK.

3. Results and Discussion

Initially, the ***Descriptive analysis of the features of Brazilian teachers*** presents the questions related to the profile of the 564 respondents resulted in a table frequency (Table 1). These questions approach data on respondents' profiles regarding gender, age, and geographic region.

Table 1. Gender, age, and geographic region of respondents.

Gender	n	%	Age	n	%	Geographic region (Brazil)	n	%
Female	341	60.46	18|--30	12	2.13	Southeast	285	50.53
Male	217	38.48	30|--40	173	30.67	South	165	29.26
Prefer not to inform	4	0.71	40|--50	206	36.52	Northeast	61	10.82
Others	2	0.35	50|--65	165	29.26	Central-West	40	7.09
			≥65	8	1.42	North	13	2.30
Total	564	100		564	100		564	100

The most respondents (60.46%) identified as female. A 2018 survey of Brazilian teachers features 79% identified as female (INEP, 2018). As for age 67.20% were at least 40. The Southeast (50.53%) and South (29.26%) concentrated most respondents. Table 2 presents information on the field of study, year of highest academic qualification, and the number of educational levels respondents taught.

Table 2. Field of study, year of highest academic qualification, and educational levels.

Field of study of highest academic qualification	n	%	Year of highest academic qualification	n	%	Number of educational levels the respondent teaches in	n	%
Humanities	173	30.67	Up to 1990	12	2.13	1	265	46.99
Hard and natural sciences	117	20.74	1990--|2000	35	6.21	2	203	35.99
Arts, Languages, and Literature	76	13.48	2000--|2010	140	24.82	3	81	14.36
Biological sciences	52	9.22	2010--|2015	139	24.65	4	15	2.66
Applied social sciences	43	7.62	2015--|2020	238	42.20			
Engineering	40	7.09						
Health sciences	34	6.03						
Agricultural sciences	25	4.43						
No answer	4	0.71						
Total	564	100		564	100		564	100

The highest academic qualification of 30.67% of respondents was in the humanities, while 20.74% was in the hard and natural sciences. As for the year of highest academic qualification, 42.20% earned some degree in the last five years, which shows a current professional development process. In addition, 24.65% indicated that their highest academic qualification happened five and ten years ago. Regarding the educational levels they teach in, 46.99% of respondents claimed to work in a single level, while 52.71% work in two or more levels simultaneously. The point here was not to suggest a greater or lesser workload but to show that teachers' preparation included greater pedagogical

complexity when working simultaneously in elementary, high school, technical, undergraduate, and graduate courses. The pedagogical complexity involved in teaching at several educational levels may reflect in adopting digital tools.

Only 0.71% of teachers did not intend to keep ICT in pedagogical practices after the pandemic (Figure 1). This fact might be an opportunity to modernize the current pedagogical context, even though not all Brazilians can access digital tools and no national training program exists to promote their use. Brazilian students scored below average in reading, math, and science (PISA, 2018). Only 2% of students achieved the highest proficiency levels (Level 5 or 6) in at least one subject. Additionally, 43% of students scored below the minimum level of proficiency (Level 2). Thus, Brazil's socioeconomic situation strongly influences students' performance. Teachers' efforts to find more efficient pedagogical alternatives can help PISA rank better. Notably, social media are helpful for professional development TPACK (VAN BOMMEL *et al.*, 2020).

Digital tools the respondent used for teaching during the pandemic and intended to continue using post-pandemic	Teachers	% concerning the total of 564 respondents
Virtual learning environments (Moodle, Google Classroom, etc.)	442	78.37
Video conference systems (Zoom, Microsoft Teams, Google Meet, etc.)	437	77.48
Videos (YouTube, Vimeo, Vevo, etc.)	436	77.30
Cloud content (Dropbox, Google Drive, Prezi, etc.)	330	58.51
Communication tools (blogs, e-mail, text messages, etc.)	328	58.16
Private social media (Facebook, Instagram, WhatsApp, etc.)	305	54.08
Institutional social media (Facebook, Instagram, WhatsApp, etc.)	280	49.65
None	4	0.71

Figure 1. Respondents' use of ICTs.

On a scale in which 1 represent totally disagree, and 5 represents totally agree, respondents answered how much they agreed with the following statement: "Exposure to information and communication technologies during the pandemic significantly changed your pedagogical activities"; the results indicated an average score of 4.37. When asked about their agreement with the statement, "When used in teaching, information and communication technologies improved pedagogical processes"; the average score was 3.70. Finally, regarding students' engagement, respondents were shown the statement, "When used in teaching, information and communication technologies increased student engagement"; the average agreement was 3.01.

Intense and immediate exposure to ICTs might have led to inadequate planning by educational institutions and education professionals, resulting in a more significant perceived impact of ICTs on teaching. The same lack of planning can affect students, which teachers may perceive as a lower student engagement with academic activities. Therefore, it inferred that teachers feel their pedagogic efforts were not proportional to student engagement. Cultural aspects and poor technological infrastructure at home might have also contributed to a lower engagement. About 18.9 million Brazilian households declared no computer and internet access (CETIC; UIS, 2020).

The ***Analysis of the variables and constructs of TPACK.xs*** started with the reliability of the questionnaire. The result to the 28 questions (0.951) indicates that the respondents' perception was coherent. However, the question number or question redundancy can result in overestimation, resulting in the expected since the questions were related to the full dimension of TPACK (SCHMID; BRIANZA; PETKO, 2020). Furthermore, the Cronbach's alpha, measured for each construct composed of four questions each, indicated consistency for constructs PK (0.85), CK (0.70), TK (0.87), PCK (0.93), TPK (0.88), TCK (0.89), and TPCK (0.95). CK had the lowest alpha, which may be due to intra-group variability. Figure 2 shows confidence interval results for each variable; questions follow the codes described in Table 3.

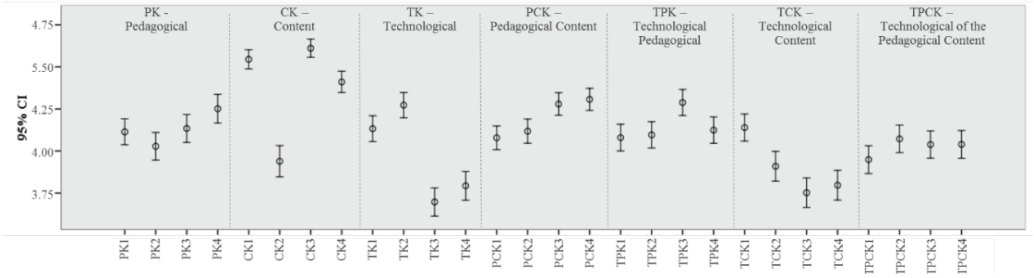

Figure 2. TPACK variables and confidence interval of choice averages.

Table 3 shows that constructs involving technological knowledge had the lowest averages. For example, TK (3.97) did not significantly differ from constructs that involve their interaction with TCK (3.90) and TPCK (4.02). These results indicate a lower agreement with the questions of these constructs compared to those of other TPACK constructs. In addition, some teachers may believe their online teaching skills to be poor. The fundamental component PK (4.13) did not significantly differ in the average of the responses when compared to its first-level hybrid components that involve the interaction with TPK (4.15) and PCK (4.20). Thus, it is easier for teachers to integrate technology and associate PCK when technology is related to their pedagogical knowledge. The CK construct (4.30) showed the highest average of responses, differing significantly from other constructs, indicating that teachers have a more excellent command of subjects, which does not imply that they sometimes fail to integrate it with other knowledge, especially concerning technologies.

Table 3. Descriptive measures.

TPACK Constructs (Mean; Standard Deviation)	Code	TPACK Variables	Mean	Standard deviation
PK	PK1	I can adapt my teaching based upon what students currently understand or do not understand	4.1142	0.9305
(4.13; 0.99)[c]	PK2	I can adapt my teaching style to different learners	4.0280	0.9924
	PK3	I can use a wide range of teaching approaches in a classroom setting	4.1340	1.0053
	PK4	I can assess student learning in multiple ways	4.2516	1.0276
CK	CK1	I have sufficient knowledge about my teaching subject	4.5450	0.6878
	CK2	I can use a subject-specific way of thinking in my teaching subject	3.9390	1.1244
(4.38; 0.87)[d]	CK3	I know the basic theories and concepts of my teaching subject	4.6110	0.6549
	CK4	I know the history and development of important theories in my teaching subject	4.4108	0.7626
TK	TK1	I keep up with important new technologies	4.1326	0.9284
	TK2	I frequently play around with the technology	4.2727	0.9087
(3.97; 1.00)[a b]	TK3	I know about a lot of different technologies	3.6968	1.0099
	TK4	I have the technical skills I need to use technology	3.7929	1.0406
PCK	PCK1	I know how to select effective teaching approaches to guide student thinking and learning in my teaching subject	4.0785	0.8516
(4.20; 0.84)[c]	PCK2	I know how to develop appropriate tasks to promote students complex thinking of my teaching subject	4.1179	0.8680
	PCK3	I know how to develop exercises with which students can consolidate their knowledge of my teaching subject	4.2793	0.8085
	PCK4	I know how to evaluate students' performance in my teaching subject	4.3069	0.7933
TPK	TPK1	I can choose technologies that enhance the teaching approaches for a lesson.	4.0794	0.9598
	TPK2	I can choose technologies that enhance students' learning for a lesson	4.0959	0.9460
(4.15; 0.95)[c]	TPK3	I am thinking critically about how to use technology in my classroom	4.2881	0.9382
	TPK4	I can adapt the use of the technologies that I am learning about to different teaching activities	4.1241	0.9489
TCK	TCK1	I know how technological developments have changed the field of my subject	4.1392	0.9759
	TCK2	I can explain which technologies have been used in research in my field	3.9090	1.0650
(3.90; 1.05)[a]	TCK3	I know which new technologies are currently being developed in the field of my subject	3.7521	1.0561
	TCK4	I know how to use technologies to participate in scientific discourse in my field	3.7965	1.0708
TPCK	TPCK1	I can use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework in my classroom	3.9486	1.0018
(4.02; 0.99)[b]	TPCK2	I can choose technologies that enhance the content for a lesson	4.0720	0.9887
	TPCK3	I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn	4.0385	0.9775
	TPCK4	I can teach lessons that appropriately combine my teaching subject, technologies, and teaching approaches	4.0394	0.9935

Note: Construct averages followed by the same letter did not differ from one another, considering a significance of 1%, as per the Tukey test.

The PK, PCK, and TPK groups, which focused on pedagogical issues, showed similar behavior, with averages ranging from 4.03 to 4.31. These groups did not differ according to the Tukey test described in Table 4, that shows the distribution of positioning frequencies and the relationship between the characterization of Brazilian teachers and TPACK constructs. The TK, TCK, and TPCK groups, which have the technological

element in common, had the lowest averages. CK had the highest overall average and the widest range among the group's variable averages. The highest average for CK may indicate that teachers are comfortable with the necessary teaching knowledge. In contrast, the widest range due to the lower average agreement with the statement "*I can use a subject-specific way of thinking in my teaching subject*." may be due to a perceived capacity to adapt and present subjects in different ways and propose learning alternatives.

Table 4. Characterization of constructs.

Constructs	n	%	Gender (%)		Age (%)		Geographic region (Brazil) (%)		Field of study of highest academic qualification (%)		Year of highest academic qualification (%)		Educational levels the respondent taught in (%)	
PK [1 2 3]	68	12.06	Female	75	18|--30	4	Southeast	53	Humanities	31	Up to 1990	0	1	57
			Male	25	30|--40	34	South	26	Hard and natural sciences	18	1990--|2000	12	2	31
					40|--50	43	Northeast	4	Arts, Languages, and Literature	15	2000--|2010	24	3	10
					50|--65	16	Central-West	15	Biological sciences	7	2010--|2015	19	4	1
					≥65	3	North	1	Applied social sciences	10	2015--|2020	46		
									Engineering	4				
									Health sciences	9				
									Agricultural sciences	4				
									No answer	1				
CK [4]	56	9.93	Female	52	18|--30	0	Southeast	52	Humanities	25	Up to 1990	4	1	36
			Male	48	30|--40	32	South	21	Hard and natural sciences	18	1990--|2000	2	2	34
					40|--50	39	Northeast	9	Arts, Languages, and Literature	13	2000--|2010	23	3	23
					50|--65	29	Central-West	16	Biological sciences	11	2010--|2015	32	4	7
					≥65	0	North	2	Applied social sciences	11	2015--|2020	39		
									Engineering	7				
									Health sciences	7				
									Agricultural sciences	7				
									No answer	2				
TK [1 5 6]	83	14.72	Female	57	18|--30	6	Southeast	49	Humanities	30	Up to 1990	1	1	49
			Male	43	30|--40	35	South	27	Hard and natural sciences	27	1990--|2000	5	2	36
					40|--50	35	Northeast	7	Arts, Languages, and Literature	17	2000--|2010	20	3	11
					50|--65	23	Central-West	12	Biological sciences	6	2010--|2015	28	4	4
					≥65	1	North	5	Applied social sciences	5	2015--|2020	46		
									Engineering	10				
									Health sciences	4				
									Agricultural sciences	1				
									No answer	1				
PCK [7]	86	15.25	Female	66	18|--30	2	Southeast	60	Humanities	40	Up to 1990	5	1	56
			Male	34	30|--40	26	South	26	Hard and natural sciences	14	1990--|2000	7	2	37
					40|--50	26	Northeast	7	Arts, Languages, and Literature	14	2000--|2010	31	3	6
					50|--65	43	Central-West	6	Biological sciences	10	2010--|2015	23	4	1
					≥65	3	North	1	Applied social sciences	7	2015--|2020	34		
									Engineering	3				
									Health sciences	7				
									Agricultural sciences	3				
									No answer	1				
TPK	36	6.38	Female	71	18|--30	0	Southeast	44	Humanities	31	Up to 1990	3	1	44
			Male	29	30|--40	33	South	36	Hard and natural sciences	17	1990--|2000	11	2	33
					40|--50	28	Northeast	3	Arts, Languages, and Literature	17	2000--|2010	22	3	19
					50|--65	39	Central-West	14	Biological sciences	8	2010--|2015	25	4	3
					≥65	0	North	3	Applied social sciences	8	2015--|2020	39		
									Engineering	6				
									Health sciences	8				
									Agricultural sciences	6				
									No answer	0				
TCK [2 5 7 8]	138	24.47	Female	47	18|--30	1	Southeast	44	Humanities	28	Up to 1990	1	1	42
			Male	53	30|--40	37	South	33	Hard and natural sciences	28	1990--|2000	5	2	38
					40|--50	34	Northeast	9	Arts, Languages, and Literature	9	2000--|2010	19	3	17
					50|--65	27	Central-West	11	Biological sciences	9	2010--|2015	27	4	3
					≥65	1	North	3	Applied social sciences	7	2015--|2020	49		
									Engineering	9				
									Health sciences	4				
									Agricultural sciences	7				
									No answer	0				
TPCK [3 4 6 8]	150	26.60	Female	47	18|--30	1	Southeast	51	Humanities	31	Up to 1990	3	1	48
			Male	53	30|--40	24	South	32	Hard and natural sciences	20	1990--|2000	5	2	35
					40|--50	42	Northeast	7	Arts, Languages, and Literature	13	2000--|2010	29	3	16
					50|--65	33	Central-West	9	Biological sciences	10	2010--|2015	17	4	1
					≥65	0	North	2	Applied social sciences	8	2015--|2020	46		
									Engineering	7				
									Health sciences	7				
									Agricultural sciences	3				
									No answer	0				

[1] Maximum agreement by a respondent tied in PK and TK; [2] Maximum agreement by a respondent tied in PK and TCK; [3] Maximum agreement by a respondent tied in PK and TPCK; [4] Maximum agreement by a respondent tied in CK and TPCK; [5] Maximum agreement by two respondents tied in TK and TCK; [6] Maximum agreement by two respondents tied in TK and TPCK; [7] Maximum agreement by a respondent tied in PCK and TCK; [8] Maximum agreement by 44 respondents tied in TCK and TPCK

The *PCA* verified that this study presents the similar structural behavior of the constructs proposed by TPACK.xs. With a commonality of 60.5%, the three factors extracted indicated the following relationships: the first component with the technological approach and its relations; the second component with the purely pedagogical field; and the third component with the content questions the subject-pedagogy composition.

Identifying these spaces enabled the inference that the data collected from the 564 Brazilian teachers confirmed the clusters proposed in TPACK.xs. Thus, it is possible to obtain a ranking for each of the seven components by PCA performing for each construct, aiming to outline a profile of Brazilian teachers regarding the components of TPACK.xs. In this study, the highest-ranking in which element of TPACK.xs best represented the teacher. Equation 1 is considered static, and the inclusion of more observations in the sample affects the scores. Therefore, the scores considered valid in this study should be produced again if another study aims to observe the same criteria.

In the case of ties, the position is assigned in both constructs. Positioning a teacher in one of the TPACK constructs does not mean they are more or less capable. It only represents how receptive, mature, or competent they are in using technological, pedagogical, and content knowledge for a paradigm shift in teaching (SCHERER *et al.*, 2021; SCHMID; BRIANZA; PETKO, 2020). The percentage distribution of teachers for the TPCK and TCK constructs, had the highest teacher densities: about 27% and 24%, respectively. TPK (6%) registered the lowest density, representing discomfort in using technologies for teaching. In contrast, the highest densities in the other interactions addressed the technological part of TPACK.xs. The fundamental constructs CK and PK (10% and 12%, respectively) were also among the lowest positioning densities, suggesting that Brazilian teachers focus on the interaction between fundamental constructs. By positioning teachers concerning constructs and using GLM, it was possible to identify which characteristics contribute most positively to the composition of each level of TPACK (p-value<0.05). Figure 3 illustrates the profiles identified and the percentage of participation in the constructs.

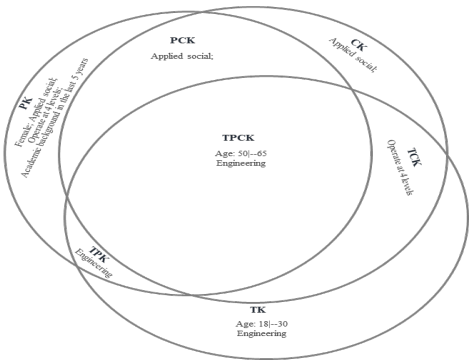

Figure 3. Profiles by construct and approximate density of classification of the TPACK.

There was a significant difference in age and field of study of the highest academic qualification to respondent profile in the TPCK construct, which suggests that teaching experience contributes to articulating the three fundamental constructs. As for the field of study, Engineering differed significantly from other fields in three of the four constructs of TPACK related to the use of technologies (TK, TPK, and TPCK). In addition, applied social sciences differed significantly in the CK, PK, and PCK constructs related to content and pedagogy. Another significant difference is observed between the ages of teachers who contributed the most in TK and TPCK. The respondents aged 18 to 30 were significantly higher in TK, indicating that younger teachers are more confident using technological resources. However, teachers aged 50 to 60 scored significantly higher in TPCK; 46% earned some degree in the last five years. Authors have indicated that previous experience in online teaching affects teachers' self-confidence and motivation in their pedagogical skills (WANG, 2022).

The data also showed that positioned in PK were 12.06% of teachers. Note that was a significant difference in self-identified female teachers' contributions compared to those of self-identified male teachers in this construct (Figure 4). A possible explanation

for this difference, evidenced in this study, is that 54.9% of females in PK earned their highest degree in the humanities (35.3%) and in the arts, languages, and literature (19.6%). In Brazil, the education major is considered part of the humanities; language and linguistics majors usually have several pedagogy courses(CAPES, 2020). In contrast, 17.6% of self-identified male teachers in PK earned a degree in the humanities and none in the arts, languages, and literature.

Figure 4 presents a word cloud with the qualitative information obtained from the open-ended question. Teachers' work at four levels of education contributed significantly to two of the seven constructs (PK and TCK), indicating that these professionals have greater flexibility to adapt to different student levels and profiles. In addition, the results indicated that the year of highest academic qualification significantly contributed to the PK construct, suggesting that teachers who underwent professional development in the last five years can access and better adapt to different, updated pedagogical methodologies. Finally, geographic regions did not significantly differ when considered in each construct of TPACK.xs. In the last question of the instrument, teachers answered to discuss the research context freely, and 126 respondents sent comments. The COVID-19 pandemic was undoubtedly present in their thoughts, especially regarding the most appropriate way to apply ICTs in schools.

Figure 4. Word cloud for open-ended questions.

As expected, the words "technology" (77), "teach" (28), "pandemic" (35), "student" (66), and "teacher" (34) stood out. "Technology" and "'teach" were frequent due to the instrument used, while the word "pandemic" was due to changes in teaching methods to adapt to the COVID-19 reality. The words "difficulty" (9), "difficult" (9), "challenge" (5), and "problem" (5) were found in smaller numbers. However, these words reached the same parameter as the most frequent words, indicating that Brazilian teachers are experiencing this moment of transformation without proper preparation or technological and pedagogical support by institutions for using ICTs (NAYLOR; NYANJOM, 2020).

These remarks on challenges point to several issues that are part of teachers' and students' lives in Brazil: (a) teachers' attitude and initiative towards the use of ICTs as pedagogical tools, impaired by the short learning time in an emergency to meet the urgent demands of remote learning; (b) difficulties in classes due to lack of adequate domestic space for teachers and students to perform pedagogical activities; (c) work/study carried out concurrently with housework and caring for children or the elderly; (d) students' lack of internet connection and devices (computer, tablets, smartphones, etc.) to do activities and communicate with teachers during remote learning; and (e) teachers' concern for student learning through digital pedagogical tools, considering students' socioeconomic condition, identified in reports of difficulties in accessing and mastering technologies.

As for theoretical implications, this study provided insight to educational researchers regarding differences in teachers' profiles and the density of teachers in each construct. In this case, Brazilian teachers showed a tendency to the interactions between TPACK's fundamental dimensions. Regarding practical implications, teachers and education professionals will have to face the results of a turning point in teaching and learning processes, considering the integration of pedagogy, content, and technology they are

exposed. Finally, as for managerial and government implications, decision-makers, managers, and policymakers will be able to rely on the results of this study to propose changes in education. Such agents can support the use of ITCs and encourage the acquisition of technological infrastructure to assist teachers and students in remote learning and in applying active pedagogical practices.

4.Conclusions

This study aimed to identify the consequences of teachers' intense exposure to digital technologies in pedagogical actions during the pandemic, outlining a profile of Brazilian teachers concerning the use of ITCs as educational tools. They employed TPACK.xs to investigate technological, pedagogical, and content aspects based on statistical analysis. The main results included the confirmation of TPACK constructs, the position of Brazilian teachers concerning TPACK, and a profile considering gender, the field of study, and the time elapsed since the last academic qualification. Their answers indicated agreement with technological components. About 57% of Brazilian teachers are positioned in technology-hybrid components, which means that teachers sought to adjust their teaching despite the mid-pandemic technological difficulties reported in content analysis. The limitations of this study included the aspects of training and school facilities not covered in this instrument, and the fully digital data collection, with no real-life contact between researchers and respondents. Future research is encouraged to examine other contexts in developed, developing, and underdeveloped countries. In addition, the difference between the mid-pandemic and post-pandemic results of TPACK.xs also merits investigation. Finally, the profiles outlined may help guide teacher training, further leading Brazilian teachers to the hybrid levels of TPACK.

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