TPACK for meaningful learning survey: "paths" for professional development of biology teachers in Brazil

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ABSTRACT
In the last decade different instruments were developed to empirically test the TPACK theoretical framework. The TPACK for Meaningful Learning survey was the first survey to obtain statistical validation for all seven predicted constructs. In the present work we used a version of the TPACK for Meaningful Learning survey adapted and validated in the Portuguese language to investigate the TPACK perceptions of Brazilian biology teachers, their interrelationships and relations with demographic variables. Results indicate a strong positive correlation between the constructs that hold the technology component. Path analysis corroborated the hypothesis that TK influences TPK and TCK, and that these two constructs directly influence TPACK. Evidence showed that the variables “age” and “years of service” influence teachers’ perceptions, especially the constructs that hold the technology component. Results obtained in the present study are discussed considering the empirical results obtained in other countries using the TPACK for Meaningful Learning survey. Taken together, our research findings contribute to foster professional development strategies for teachers that aim at the integration of technologies in teaching.
Keywords: in-service biology teachers, professional development, country-specific developments, technological pedagogical content knowledge

1. Introduction and literature review
1.1. TPACK theoretical framework
Teaching is characterized by a great diversity of situations faced by teachers, including the interconnections between theory and practice, requiring interweaving of different types of knowledge applicable in different situations. Based on this proposition, Lee Shulman (1986, 1987) argued that content and pedagogy were combined in the minds of experienced teachers, to the point of generating a kind of knowledge distinct from the knowledge of a pedagogue and that of an expert in a given area of knowledge. This specific knowledge, the Pedagogical Content Knowledge, reflects how solutions for learning issues can be presented, adapted, and organized for instruction as specific topics (Shulman, 1986, 1987).

According to Shulman’s (1986, 1987) views, specific teaching topics could be represented using different approaches, as demonstrations, analogies, examples, explanations what will turn the contents more comprehensive. Mishra and Koehler (2006) argued that technologies will play essential function in each of these aspects. In such, technologies may assist teachers by making contents more accessible to students by providing a range of representation and demonstration possibilities (Mishra & Koehler, 2006). These authors proposed the theoretical framework Technological Pedagogical Content Knowledge (TPACK), which theoretically predicts the interrelationship not only of pedagogical knowledge with content, but also of these two with technological knowledge. This theoretical formulation enabled to predict the existence of seven different constructs. Box 1 presents conceptual definitions based on Chai, Koh and Tsai (2011), Koh, Chai and Tsai (2013) and Mishra and Koehler (2006), as well as examples for each of the seven constructs foreseen in the TPACK theoretical framework.

The addition of technological knowledge (TK) to the pedagogical content knowledge (PCK) provided a new approach to address integration of technology in teaching. Since then, means to assess teachers' TPACK perceptions have been sought and proposed. Many writers are especially concerned with the processes by which technology would integrate with content and pedagogy (Chai, Koh, & Tsai, 2013, Graham, 2011, Herring, Koehler, & Mishra, 2016, Niess, 2011, Voogt, Fisser, Roblin, Tondeur, & van Braak, 2013, Wu, 2013, Willermark, 2017), as well its relationship with age and field experiences affects the technology integration of preservice and in-service teachers, in special their beliefs and intentions (Cheng & Xie, 2018; Nelson & Hawk, 2020).

The TPACK theoretical framework is important for the area of research on teacher´s education aiming at allowing the integration of technologies into their pedagogical practices (Herring et al, 2016, Graham, 2011, Wu, 2013). Researchers worldwide studied how teachers perceive their knowledge on integrating technology into teaching using different methods. TPACK measurements can happen in many formats. It can be done by interviews, artifact or field observations, surveys, and performance-evaluation instruments or open-ended questionnaires (Koehler, Shin, & Mishra, 2012; Voogt et al, 2013). Willermark (2017) in systematic literature review about application of how to measure TPACK framework, showed that there are many approaches and instruments to evaluate teacher TPACK knowledge, however the most common were self-reports. Akyuz (2018) compared TPACK performance-assessment vs. self-assessment of pre-service Math teachers and found to yield similar results except for pedagogy constructs.

Box 1. Definitions and examples for TPACK constructs

Constructs	Definition*	Example **
Content Knowledge (CK)	Knowledge about content.	Knowledge about Biology.
Pedagogical Knowledge (PK)	Knowledge about teaching methods.	Knowledge of how to use problem-based learning.
Pedagogical Content Knowledge (PCK)	Knowledge about the adoption of pedagogical strategies to make contents more understandable for students.	Knowledge on how to conduct practical classes to teach biological concepts.
Technological Knowledge (TK)	Knowledge on technological tools.	Knowledge on how to use Web 2.0 tools (example Wiki, Blogs, Facebook).
Technological Pedagogical Knowledge (TCK)	Knowledge of how to use technology to represent contents in different ways.	Knowledge on how to use animations to present the processes of embryonic development.
Technological Content Knowledge (TPK)	Knowledge on using technology to implement different teaching methods.	Knowledge on using Wiki as a communication tool to increase collaborative learning.
Technological Pedagogical Content Knowledge (TPACK)	Knowledge on using technology to implement teaching methods of different types of content.	Knowledge on using Wiki as a communication tool to increase collaborative learning in biological concepts

* Based in Chai, Koh and Tsai (2011), Koh, Chai and Tsai (2013) and Mishra e Koehler (2006).
** Examples adapted to biological knowledge.

1.2. TPACK for meaningful learning surveys
Several instruments aimed at testing empirically the seven constructs predicted by Mishra and Koehler (2006) in the TPACK theoretical framework were developed (Chai, Koh & Tsai, 2016; Willermark, 2017). From a systematic review of the literature, Voogt et al (2013) found 11 studies related to the measuring of TPACK teachers´ constructs using surveys. Eight out of eleven studies used statistical tests to evaluate the psychometric properties of the developed surveys. Among these studies, the work of Schmidt, Baran, Thompson, Mishra, Koehler, and Shin (2009); Chai, Koh, & Tsai (2010); Koh, Chai, & Tsai (2010); Chai, Koh, & Tsai (2011) are highlighted as a sequence of attempts to validate instruments composed of similar sets of items.

The study by Chai et al (2011) was the first to obtain statistical validation for the seven constructs using the TPACK for Meaningful Learning survey (TPACK-SML). The TPACK-SML was responded by three hundred and thirty-six Singaporean preschool teachers from a 3month course about integration of ICT for teaching and learning. Another use of this survey was carried out with 455 practicing teachers in Singapore (Koh et al., 2013).

These participants were recruited from a professional ICT development program promoted by an Research Project. Once again, the TPACK-SML obtained statistical validation for the seven constructs, demonstrating its validity and reliability (Koh et al., 2013). In 2013, one more slightly modified version of TPACK-SML was answered by 366 Taiwanese teachers (Liang, Chai, Koh, Yang, & Tsai, 2013). Although items related to Content Knowledge were not changed, new items were added to the other constructs. In addition, adaptations were made to direct the focus of the TK construct to Web-based technologies (Liang et al., 2013). The factorial analysis resulted in the validation of only six constructs, since the pre-determined items for TPK and TCK were grouped into a new factor called TPTCK (Liang et al., 2013).

In other new use of TPACK-SML with teachers from Singapore, Koh and Chai (2014) investigated TPACK perceptions of teachers before and after participating in a course focused on the elaboration of lesson plans using Information and Communication Technologies (ICT). This version of TPACK-SML presented statistical validation for the seven constructs predicted in the TPACK theoretical framework, demonstrating its validity and reliability (Koh & Chai, 2014). More recently, Liu, Zhang and Wang (2015) obtained responses from 2728 Chinese teachers for a modified version of the TPACK-SML. The authors retained the essence of the original items used by Koh and Chai (2014). Additional adaptations were made to direct the focus of items to multimedia technologies. However, this survey obtained statistical validation for only five constructs to know: CK, PK, TK, PCK and a combined factor, called TPK-TCK-TPACK (Liu et al., 2015).

1.3. The Brazilian TPACK for meaningful learning survey

Systematic study reviews of TPACK theoretical framework published in English language did not recover studies related to the Brazilian context (Chai et al., 2013, Koehler et al., 2012, Voogt et al., 2013). Recently, systematic reviews carried out with studies in Portuguese language indicated that the scientific production in Portuguese-speaking countries is at early stage. In these studies, reports mainly point out TPACK as an important theoretical framework, although no study attempted to measure different type of teachers' knowledge on integration of technology in teaching (Rolando, Luz & Salvador, 2015; Nogueira, Pessoa & Gallego, 2015). According to these authors, no records of studies on the validation of surveys on teachers' perceptions about TPACK constructs in Portuguese-speaking countries were reported.

In order to fill this gap, the TPACK-SML version validated by Koh et al (2013) was submitted to the process of cross-cultural adaptation (Beaton, Bombardier, Guillemin & Ferraz, 2000), generating a Brazilian version of the TPACK-SML in Portuguese language (Rolando et al., 2018). This version obtained statistical validation through factorial analysis for the seven TPACK constructs.

2. Research questions

The present study aims to measure TPACK perceptions of Brazilian biology teachers, their interrelationships and relations with demographic variables, as well as to discuss them in a way that indicate possibilities of action in teachers` professional development programs. Therefore, we organized our results section into two subsections, each one related to a specific research question:

- What TPACK constructs should be emphasized in future professional development programs for teachers so that they enhance their ability to integrate technologies in teaching of biology?

- Do the variables “age” and “years of service” influence the confidence of biology teachers in relation to the seven constructs of the TPACK theoretical framework?

3. Methodology

3.1. Participants and context of the study

A total of 440 biology teachers from the public education network of the State of Rio de Janeiro, Brazil, participated in this study. Participating teachers attended the Teacher Education Program (TEP), offered by the State Department of Education of Rio de Janeiro in partnership with the Foundation Center of Science and Higher Distance Education of the State of Rio de Janeiro (https://www.cecierj.edu.br/). Teachers were of around 40.08 years old (Desvp = 9.40); 12.63 years of service (Desvp = 8.45) and 72.5% of participants were women.

The TEP was structured as a course offered remotely by means of a virtual learning environment (VLE) built on the Moodle educational platform (Modular Object-Oriented Dynamic Learning Environment). The distribution of didactic material, the online activities, as well as the interaction between the course participants and tutors responsible for conducting them took place in the VLE. The course was structured in three stages: (i) planning, (ii) implementation, and (iii) evaluation. In the planning stage, a broad set of materials was made available to the course participants; lesson plans, learning objects, texts in PDF for printing, images, videos and animations directed to the teaching of major subjects of Biology (example, Energy sources, Diversity of living beings, Ecosystems, Biotechnology, among others). After exploring the didactic material, participants elaborated a lesson plan to guide their teaching in the classroom during the implementation phase. Both in the planning and implementation stages, course participants took part in a thematic forum for online discussion with their peers and tutors. In the evaluation stage, course participants rewrote the lesson plan based on the feedback obtained in the implementation stage.

Teachers were invited to participate in the present study through an official communication of the general coordination of the TEP via e-mail. This message presented the subject of the survey to those enrolled in the TEP, indicated the electronic address of the survey to be answered and made informed consent forms available.

3.2. Instrument of data collection

The instrument used to collect the data analyzed in this study was the Brazilian version of TPACK-SML (Rolando et al., 2018). This survey covers 29 items measured at a 7-point Likert-type scale rated as (1) strongly disagree, (2) disagree, (3) slightly disagree, (4) neither agree nor disagree, (5) slightly agree, (6) agree, and (7) strongly agree.

According to Chai et al (2016) the TPACK for Meaningful Learning was progressively formulated and revised towards meaningful learning with an ICT framework (Howland, Jonassen, & Marra, 2012). The term "Meaningful Learning" used in the formulation of items related to pedagogical knowledge refers to the five dimensions of meaningful learning (active, cooperative, constructive, intentional and authentic) (Howland et al, 2012).

The Brazilian version of TPACK-SML uses the term Biology to refer to the CK construct since it was used exclusively with teachers of this subject. This approach allowed a more in-depth discussion on teacher training related to the integration of technology in biology teaching. Appendix 1 contains the Brazilian version of TPACK-SML and the mean scores for each of the seven constructs and the 29 items. The reliability of the survey was high, with overall Cronbach alpha of 0,923. Reliability of the seven TPACK constructs was also established as each presented high Cronbach alphas as: CK (α= 0,846), PK (α= 0,854), TK (α= 0,851), PCK (α= 0,853), TPK (α= 0,878), TCK (α= 0,752), TPACK (α= 0,759) (Rolando et al., 2018). All coefficients exceeded recommended minimum value of α = 0.70 (Hair, Anderson, Tathan, Black, 2010; Nunnally, 1967). The confirmatory factorial analysis showed satisfactory model fit in relation to the studied sample (χ^2 = 906,126, χ^2/df = 2,545, p <0.001, TLI = 0.909, CFI = 0.920, RMSEA = 0.059). Factors loaded according to the pre-defined structure for all seven TPACK constructs with loadings larger than 0.50 (Rolando et al., 2018).

3.3. Data analysis

To proceed with the structural equation modeling, more specifically to the confirmatory factor analysis followed by the path diagram structural equation model, the maximum likelihood method was used. To perform path analysis, the AMOS v.22 software was used. In this analysis the following statistical criteria were used: Chi-square (χ^2), Root Mean Square Error of Approximation (RMSEA), Chi-square normalized (χ^2/df), Tucker-Lewis index (TLI) and Comparative fit index (CFI). The path analysis has been used by many authors to verify association within TPACK constructs, and between the constructs and other aspects and variables of preservice and in-service teachers (Cheng & Xie, 2018; Taimalu & Luik, 2019; Nelson & Hawk, 2020).

Analysis of correlations between the TPACK constructs and those using the demographic variables "age" and "years of service" was performed using the Pearson correlation. To perform correlation tests, the GraphPad Prism v.5 software was used. Statistical analyzes are based on the precepts of Fraenkel and Wallen (2008), according to correlation coefficients (r) values between 0.41 and 0.60, large enough for practical and theoretical use. According to these authors, values of r between 0.61 and 0.80 are considered especially important in the research context.

4. Results

4.1. What TPACK constructs should be emphasized in future professional development programs for teachers so that they enhance their ability to integrate technologies in teaching of biology?

Based on the theoretical assumptions of Shulman (1986, 1987) and Mishra and Koehler (2006) concerning the interrelationship between different types of knowledge (CK, PK, TK), and also the emergence of different intermediary knowledge (PCK, TCK, TPK) and the TPACK as integrated knowledge, we tested the hypothetical model (Figure 1), aiming at identifying possible influence relations amongst the seven predicted constructs:

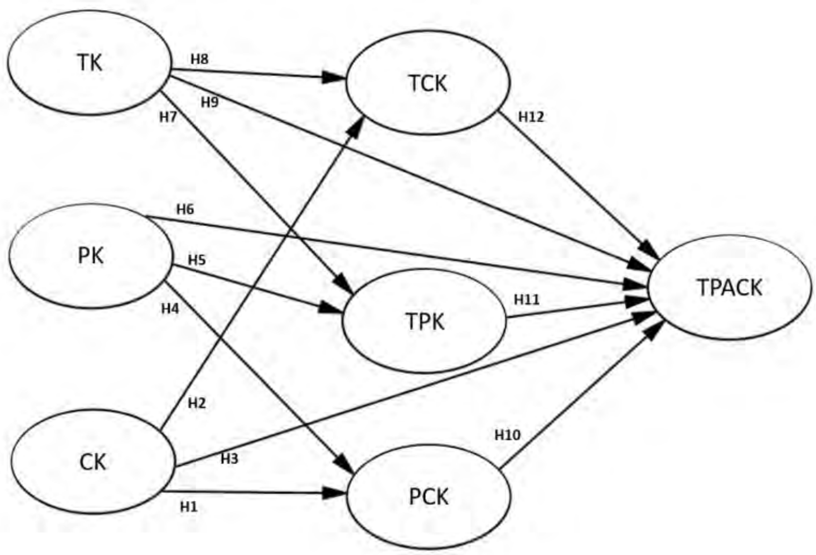

Figure 1. The hypothesized path model

The feasibility of testing this model by the analysis of correlations amongst the seven constructs was verified. Positive correlations with significance level of $p < .01$ among all the TPACK constructs were obtained (Table 1). Together, these results indicate that these relationships can be analyzed using the path diagram structural equation model.

Table 1. Inter-correlations among constructs

	CK	PK	PCK	TK	TPK	TCK	TPACK
CK	1						
PK	.350**	1					
PCK	.393**	.341**	1				
TK	.349**	.304**	.214**	1			
TPK	.274**	.520**	.194**	.622**	1		
TCK	.261**	.358**	.208**	.628**	.628**	1	
TPACK	.349**	.492**	.248**	.580**	.668**	.650**	1

** Correlation is significant at the .01 level.

To test the hypothetical model proposed in Figure 1, a path model with structural equation modeling was used (Figure 2). Confirmatory factor analysis showed satisfactory Goodness-of-Fit Measures indexes in relation to the studied sample ($\chi^2 = 968.805$, $\chi^2/df = 2.676$, $p < 0.0001$, TLI = 0.901, CFI = 0.912, RMSEA = 0.062).

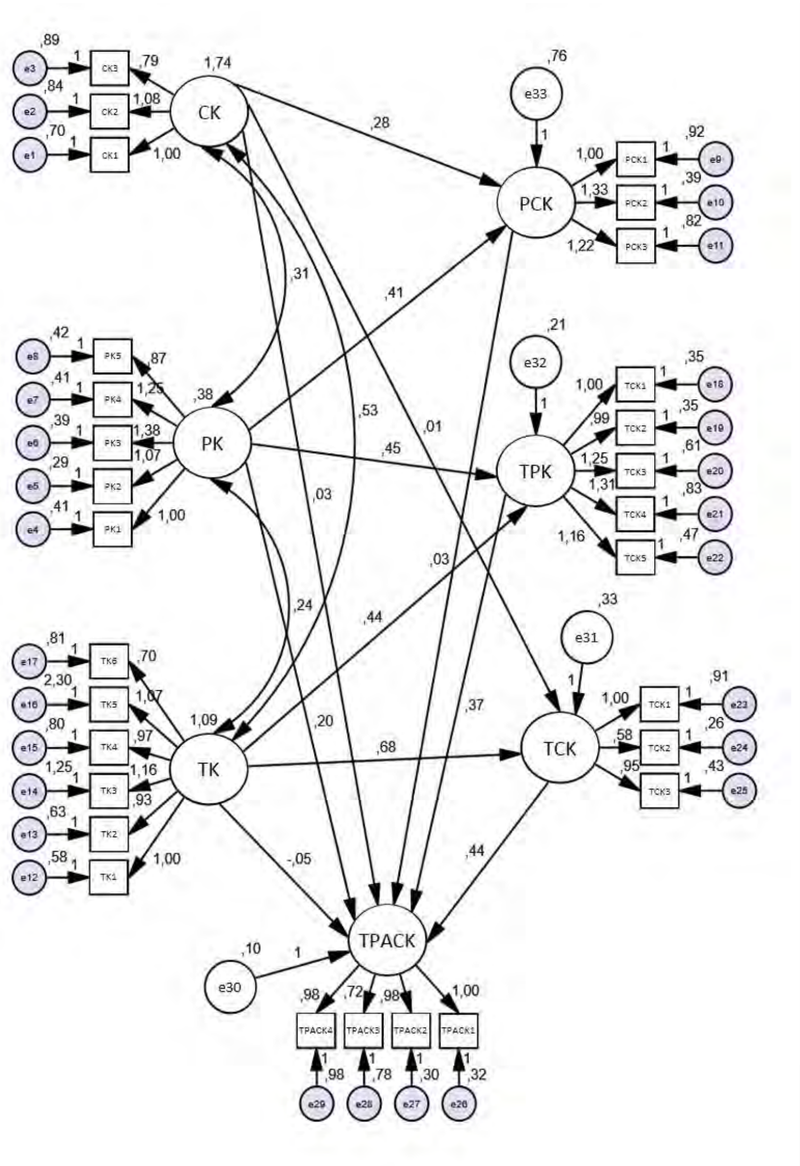

Figure 2. Path diagram structural equation model

The hypotheses H1, H4, H5, H6, H7, H8, H11 and H12 were corroborated (Table 2). In summary, these results indicate:

(i) The CK influences only the PCK (H1). On the other hand, the PCK does not influence the TPACK (H10). This result shows that the CK does not influence directly on the constructs that hold the "Technology" component.

(ii) The PK influences the PCK and the TPK (H4 and H5), as well as the TPACK (H6). This result indicates that the PK influences directly the constructs that hold the Technology component.

(iii) The TK influences the TPK and the TCK (H7 and H8), but not directly the TPACK (H9). This result show that the TK might influence the TPK and the TCK constructs, and that these two, in turn, influence directly the TPACK (H11 and H12).

Table 2. TPACK structural equation model path coefficients

Hypothesis	Path			Path coefficient	Standard error	Critical ratio	P
H1	CK	--->	PCK	.275	.045	6.179	***
H2	CK	--->	TCK	.007	.034	0.219	.827
H3	CK	--->	TPACK	.029	.026	1.125	.261
H4	PK	--->	PCK	.414	.093	4.478	***
H5	PK	--->	TPK	.449	.059	7.640	***
H6	PK	--->	TPACK	.196	.061	3.206	.001
H7	TK	--->	TPK	.438	.037	11.774	***
H8	TK	--->	TCK	.685	.059	11.607	***
H9	TK	--->	TPACK	-.045	.066	-0.689	.491
H10	PCK	--->	TPACK	.026	.031	0.853	.394
H11	TPK	--->	TPACK	.369	.069	5.388	***
H12	TCK	--->	TPACK	.441	.068	6.524	***

***p< .0001

4.2. Do the variables "age" and "years of service" influence the confidence of biology teachers in relation to the seven constructs of the TPACK theoretical framework?

Hypotheses:

H1. The younger the teacher, the greater the confidence in his / hers TK, TPK, TCK and TPACK.

H2. The longer the years of service, the greater the teacher's confidence in relation to his / hers PK and PCK.

Regarding the use of technology, hypothesis H1 stems from the idea that young teachers would be the so-called digital natives, due to early exposure to the technology and the internet. Older teachers, however, could be considered digital immigrants, as they find themselves in the midst of changing of customs and habits (Prensky, 2001; Székely & Nagy, 2011). In this perspective, older teachers would have greater difficulty adapting to the use of new tools and technological resources. On the other hand, H2 is justified since their longer experience in teaching brings greater confidence in relation to the constructs that hold the pedagogical component (Shulman, 1987).

Table 3 presents correlation results between variable "age" and each of the seven constructs. As stated in hypothesis H1, negative correlations between teacher's age and their confidence in relation to TK, TPK, TCK and TPACK were found. The small R^2 values obtained suggest evidence that the "age" variable influences teachers' confidence in relation to TK, TPK, TCK and TPACK, but it does not explain only by itself the observed covariations. On the other hand, no correlation was found between the teacher's "age" and the constructs that do not hold the technology component (Table 3).

Table 3. Correlations between variable "age" and constructs

Constructs	Pearson r	95% Confidence Interval	*p* (two-tailed)	R^2
CK	-.02237	-0.1156 to 0.07129	.6399	.0005002
PK	.07109	-0.02257 to 0.1635	.1366	.005053
PCK	-.03398	-0.1271 to 0.05972	.4772	.001154
TK	-.2835	-0.3673 to -0.1952	P<.0001	.08040
TPK	-.1578	-0.2476 to -0.06524	.0009	.02490
TCK	-.1955	-0.2838 to -0.1039	P<.0001	.03822

TPACK	-.1029	-0.1946 to -0.009515	.0309	.01059

Table 4 shows correlation results between the variable "years of service" and each of the seven constructs. A positive correlation was observed between "years of service" and the PK variable, indicating that as the teaching time increases, the pedagogical knowledge of the teacher also increases, partially corroborating the H2 hypothesis. No correlations were found between the variable "years of service" and the CK, PCK and TPACK (Table 4).

Table 4. Correlations between variable "years of service" and constructs

Constructs	Pearson r	95% Confidence Interval	*p* (two-tailed)	R^2
CK	-.02317	-0.1164 to 0.07049	.6280	.0005366
PK	.1316	0.03861 to 0.2224	.0057	.01733
PCK	.007696	-0.08587 to 0.1011	.8721	.00005923
TK	-.2183	-0.3056 to -0.1274	P<.0001	.04765
TPK	-.1248	-0.2158 to -0.03167	.0088	.01558
TCK	-.1163	-0.2076 to -0.02306	.0146	.01353
TPACK	-.05631	-0.1490 to 0.03739	.2385	.003171

There are negative correlations between the variable "years of service" and teacher confidence in relation to constructs TK, TPK, TCK (Table 4). These results indicate that the longer the "years of service", the lower is their confidence in the TK, TPK and TCK. However, R^2 values obtained are low, indicating that factors other than "years of service" influence the observed correlations. This finding may be related to the strong correlation found between the variables "age" and "years of service" ($p < .0001$; R squared 0.5628), reinforcing findings on the H1 hypothesis.

5. Discussion

Analysis of teachers' perceptions on different constructs foreseen in the TPACK theoretical framework is an important and growing trend in the last decade, especially the collection of data using surveys (Abbitt, 2011; Chai et al., 2013; Voogt et al., 2013; Willermark, 2017). Among several attempts of psychometric validation using statistical tests of validity and reliability, we highlight the results obtained with the TPACK-SML, validated in different countries; Singapura (Chai et al., 2011; Koh et al., 2013; Koh & Chai, 2014), Taiwan (Liang et al., 2013) and China (Liu et al., 2015), and more recently in Brazil (Rolando et al., 2018).

Results obtained in the present study confirm previous findings that all seven constructs are positively correlated with each other (Chai et al., 2011; Koh et al., 2013). Our results also indicate a strong positive correlation between the constructs that hold the technology component. These correlations were confirmed by the path analysis technique, which corroborated the hypotheses that TK influences the intermediary constructs TPK and TCK, and that these two constructs, in turn, directly influence the TPACK construct.

Koh et al (2013) obtained similar results with teachers in Singapore, especially on the implication from TPK and TCK on TPACK. Results showed that teachers make four direct paths to TPACK. There paths are TK, PK, TCK, and TPK. They also found that TK and PK to have some direct effects on TPACK. However, TCK and TPK showed larger path coefficients, showing that these have stronger direct effects on TPACK than TK and PK. In view of these findings, we can argue that TK does not seem to be as important as the intermediary constructs TPK and TCK when teacher´s confidence in relation to TPACK is considered. It is reasonable to assume that knowledge about technologies, such as the use of computers or social media, becomes an important factor of confidence so that the teacher perceives him/herself capable of integrating these same technologies into his/her teaching practice. For instance, by mastering these technologies, he/she becomes able to help students to use them in order to search more information autonomously (TPK2). Likewise, biology teachers are greatly confident about the TCK, especially about their ability to use technologies to research on biology and use multimedia resources as animations to convey some biological contents.

It was also observed that the PK influences the intermediary constructs PCK and TPK, as well as TPACK but in a low or moderate manner. These results, like those found by Koh et al (2013), indicate that teachers were more confident about general pedagogical knowledge related to pedagogical processes and methods than to teaching processes closely related to the content itself (PCK). The fact that the CK influences only the PCK, and that PCK, in turn, does not directly influence the TPACK, corroborates this interpretation.

In relation to our first research question, the above results suggest that professional development programs aiming to improve teachers´ TPACK should emphasize the TCK and TPK constructs as well as the interrelationship between them. Such programs could create opportunities for teachers to develop the ability to integrate their knowledge of TICs that present biological contents (examples; videos, animations and simulators) with TICs that enable the creation of processes based on active learning and teaching methodologies (examples; collaborative learning and problem-based learning). Technological resources, such as animations, have the potential to increase the visualization of processes and natural phenomena (Teixeira, Benchimol, Crepaldi & de Souza, 2012; Mayer, 2002), facilitating the understanding of contents considered difficult for students, as proposed by Mishra and Koehler (2006). On the other hand, TICs as virtual learning environments or social network softwares can be used by teachers to increase collaboration among students, while they are being guided to seek solutions to real problems related to contemporary issues involving biological knowledge.

The proposition to emphasize the TCK and TPK constructs is also valid when we consider the context faced by Brazilian teachers. Recent research reports that only 11% of Brazilian schools house science laboratories, making it difficult to teach biology through laboratory practices (QEdu Academia, 2014). However, 61% of these schools have access to the internet and 45% have computer labs (QEdu Academia, 2014). This infrastructure could be used to mitigate the lack of science laboratories, enabling teachers to make use of technological resources. This finding does not at all suggest that Science laboratories should or could be replaced by computer facilities but only that the latter could prove helpful when and while more effective solutions are unavailable.

Turning to the second research question, the hypothesis that a young teacher may be more confident about his TK than an older teacher is supported, at least in part, by the influence of the variable "age" on teacher´s confidence in relation to the constructs TK, TPK, TCK and TPACK. This hypothesis is also supported by the negative relation between years of service and confidence in the constructs that hold the Technology component.

Together, these data corroborate results found by Liang et al (2013) and Liu et al (2015). According to these two studies, more experienced teachers have less knowledge about ICTs and on how to teach using these technologies (Liang et al, 2013; Liu et al, 2015). Liu et al. (2015) found a negative relationship between the variable “years of service” and the confidence in their own technological knowledge. Teachers who had between 1 and 5 years of service presented scores significantly higher than those ranging from six to more than 20 years of service (Liu et al., 2015). On the other hand, teachers who had six or more years of service were more confident about PK than beginners (1 to 5 years of service) (Liu et al., 2015).

Nelson & Hawk (2020) using structural equation modeling to predicted beliefs and intentions changes, described that technology utility can predict intentions to use technology and Meaningful Learning strategies, which will foster technology integration among teachers. It shows the impact of field experiences on beliefs and intentions of preservice teachers, where they will see technology in classroom frequently and watch the skilled teachers using meaningful learning strategies in integrated mindset. Furthermore, Cheng & Xie (2018) for in-service teachers showed how value beliefs around technology integration are the most important aspects to produce TPACK integration. It means that in addition to knowledge, beliefs also impact the integration of technology. However, Taimalu & Luik (2019) in a path analysis of TPACK for in-service teachers showed that only technology knowledge and have direct influence on technology integration. The beliefs about technology value have indirectly influenced on technology integration. Moreover, pedagogical knowledge had a significant influence on technology integration. Scherer et al. (2018) using many structural equation modeling approaches discuss that the attitudes toward technology and TPACK self-beliefs were well associated. However, the attitudes and TPACK dimensions has differences.

In the present study we have also found evidence that the variables “age” and” year of service” influence teacher´s knowledge, especially on the constructs that include the technology component. This greater mastery of the constructs related to the technology knowledge by younger teachers is corroborated by two previous studies. According to Martins et al. (2015), 50% of pre-service Biology teachers made weekly use of Internet tools to study biology. In another study, Rolando, Salvador & Luz (2013) showed that only 26% of in-service Brazilian biology teachers used those tools to study whilst only 7% used them to teach. On the other hand, the present study show that more experienced teachers report greater confidence in the PK than more inexperienced teachers.

Although the correlations found have small explanatory value, it seems valid to take them into account when formulations of proposals are aimed at improving teachers' TPACK. It is reasonable to speculate that the promotion of collaborating activities between teachers with more years of service with novice or even pre-service teachers could be a strategy to be adopted by teachers´ education programs, aiming at the sharing of technological knowledge and teaching experience.

7. Conclusions and implications

Statistical validation of the TPACK-SML obtained by Chai et al. (2011) opened perspectives for the accomplishment of several empirical studies aimed at assessing teachers' perceptions of the TPACK. This instrument has been adapted and used in different countries and more recently in Brazil. These studies focused mainly on validation results and/or the analysis of statistical interrelations between the constructs among themselves and with other socio-demographic variables.

Teachers analyzed in the present study were more confident about the knowledge that holds the technology component (TK, TCK, TPK and TPACK). Among them, the TCK stands out, indicating that the teachers can research with the use of technologies, as well as use multimedia resources and simulators to represent Biology contents. The relationships between the constructs that hold the technology component presented r values greater than between those that do not hold this component. The path analysis employed in this study indicated that TK influences TPK and TCK, which in turn directly influence the TPACK. Regarding the relationships between the seven constructs of the TPACK framework with the demographic variables as "age" and "years of service", there were indications that these variables could influence teachers' knowledge.

Based on the findings so far, it is possible to indicate that programs aimed at improving teachers' TPACK could include activities that stimulate the combination of the TCK and TPK that can be brought in when experienced and novice teachers collaborate.

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Appendix 1

Brazilian version of the TPACK for Meaningful Learning survey (Rolando et al., 2018) and average scores for each of the seven constructs as well as for the 29 items. This survey is based on TPACK-SML version validated by Koh et al (2013) submitted to the process of cross-cultural adaptation (Beaton, Bombardier, Guillemin & Ferraz, 2000), generating a Brazilian version of the TPACK-SML in Portuguese language.

Items	**Mean**	**SD**
Content Knowledge (CK)	**4,88**	**1,36**
CK1 – I have sufficient knowledge about Biology	5,14	1,56
CK2 – I can think about Biology like a expert	4,25	1,69
CK3 – I am able to develop deeper understanding about Biology	5,25	1,40
Pedagogical Knowledge (PK)	**5,63**	**0,74**
PK1 – I am able to stretch my students' thinking by creating challenging tasks for them	5,70	0,89
PK2 – I am able to guide my students to adopt appropriate learning strategies	5,68	0,85
PK3 – I am able to help my students to monitor their own learning	5,42	1,06
PK4 – I am able to help my students to reflect on their learning strategies	5,50	1,01
PK5 – I am able to guide my students to discuss effectively during group work	5,83	0,84
Pedagogical Content Knowledge (PCK)	**5,01**	**1,29**
PCK1 – Without using technology, I can address the common misconceptions my students have for Biology	5,19	1,40
PCK2 – Without using technology, I know how to select effective teaching approaches to guide student thinking and learning in Biology	5,00	1,48
PCK3 – Without using technology, I can help my students to understand Biology through various ways	4,84	1,53
Technological Knowledge (TK)	**5,18**	**1,10**
TK1 – I have the technical skills to use computers effectively	5,73	1,29
TK2 – I can learn technology easily	5,76	1,25
TK3 – I know how to solve my own technical problems when using technology	4,73	1,65
TK4 – I keep up with important new technologies	5,34	1,36
TK5 – I am able to create web pages	3,53	1,88

TK6 – I am able to use social media (e.g. Blog, Wiki, Facebook)	5,98	1,16
Technological Pedagogical Knowledge (TPK)	**5,53**	**0,94**
TPK1 – I am able to use technology to introduce my students to real world scenarios	5,82	0,97
TPK2 – I am able to facilitate my students to use technology to find more information on their own	5,81	0,97
TPK3 – I am able to facilitate my students to use technology to plan and monitor their own learning	5,27	1,24
TPK4 – I am able to facilitate my students to use technology to construct different forms of knowledge representation (text, graphic, table, image, video, comics, etc.)*	5,22	1,36
TPK5 – I am able to facilitate my students to collaborate with each other using technology	5,51	1,13
Technological Content Knowledge (TCK)	**5,82**	**0,88**
TCK1 – I can use the software that are created specifically for Biology (armazenadores de dados, Enciclopédia Multimídia Seres Vivos®, Corpo humano e sistemas P3D, entre outros)**	5,36	1,33
TCK2 – I know about the technologies that I have to use for the research about Biology	6,27	0,74
TCK3 – I can use appropriate technologies (e.g. multimedia resources, simulation) to represent the Biology	5,82	1,10
Technological Pedagogical Content Knowledge (TPACK)	**5,68**	**0,79**
TPACK1 – I can teach lessons that appropriately combine Biology, technologies and teaching approaches	5,75	0,94
TPACK2 – I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn	5,82	0,92
TPACK3 – I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom	5,87	1,04
TPACK4 – I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school	5,30	1,24

* Example of forms of knowledge representation
** Examples of softwares are presented in Portuguese language, as they are proper names.