Analysis of technological pedagogical content knowledge in teachers of mathematics and language and literature subjects

Domingo Felipe Aráuz Chévez[1]
domingo.arauz@fh.unanleon.edu.ni
https://orcid.org/0000-0003-2915-1198
National Autonomous University of Nicaragua-León (UNAN-León)
León, Nicaragua

Martha Chavarría Guido[2]
marthachavarria@fh.unanleon.edu.ni
https://orcid.org/0000-0001-5675-9997
National Autonomous University of Nicaragua-León, (UNAN-León)
León, Nicaragua

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Abstract

The aim of this research is to analyze the Technological Pedagogical Content Knowledge (TPCK) of teachers of Mathematics and Language and Literature subjects in a secondary school in Nicaragua, specifically in the three dimensions of this theoretical model: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK). The study was developed under a comparative descriptive approach, with the participation of 11 teachers (5 Mathematics teachers and 6 Language and Literature teachers). For the data collection, an online questionnaire was applied to the teachers and analyzed through comparative tables of the three dimensions of the TPCK. The results indicate that there is more evidence of Technological Pedagogical Content Knowledge in Mathematics teachers than in Language and Literature teachers. It is concluded that there is a need to support teachers in both disciplines in specific areas of the TPCK to improve their skills.

Keywords: Technological pedagogical knowledge of content; secondary school teacher, mathematics, Language and Literature

Análisis del conocimiento tecnológico pedagógico del contenido en los docentes de las asignaturas de matemática y lengua y literatura

Resumen

El objetivo de esta investigación es analizar el Conocimiento Tecnológico Pedagógico del Contenido (TPCK) en los docentes de las asignaturas de Matemáticas y de Lengua y Literatura de una escuela de secundaria de Nicaragua, específicamente en las tres dimensiones de este modelo teórico: Conocimiento Pedagógico del Contenido (PCK), Conocimiento Tecnológico del Contenido (TCK) y Conocimiento Tecnológico Pedagógico (TPK). El estudio se desarrolló bajo un enfoque descriptivo comparativo, en el que participaron 11 docentes (5 de Matemáticas y 6 de Lengua y Literatura). Para el levantamiento de los datos se aplicó un cuestionario en línea a los docentes y se analizó a través de tablas comparativas de las tres dimensiones del TPCK. Los resultados indican que existen mayores evidencias de conocimiento Tecnológico

Pedagógicos del Contenido en los docentes de Matemática que en los de Lengua y Literatura. Se concluye la necesidad de apoyar a los docentes de ambas disciplinas en áreas específicas del TPCK para mejorar sus capacidades.
***Palabras clave*:** Conocimiento tecnológico pedagógico del contenido; profesor de secundaria, matemática, Lengua y Literatura.

Análise do conhecimento tecnológico e pedagógico de conteúdos de professores de disposições de matemática e língua e literatura

Resumo

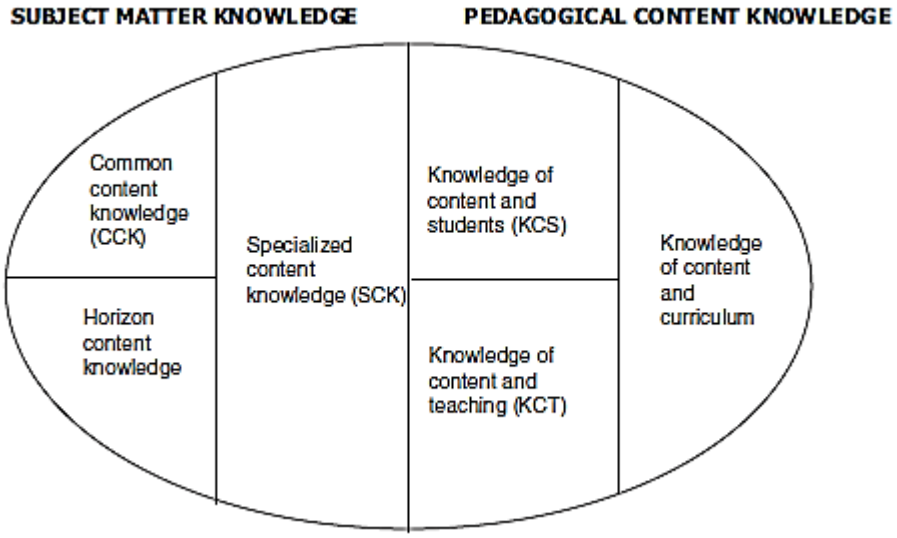
O objectivo desta investigação é analisar o Conhecimento de Conteúdo Pedagógico Tecnológico (TPCK) de professores de Matemática e de Língua e Literatura numa escola secundária da Nicarágua, especificamente nas três dimensões deste modelo teórico: Conhecimento de Conteúdo Pedagógico (PCK), Conhecimento de Conteúdo Tecnológico (TCK) e Conhecimento Pedagógico Tecnológico (TPK). O estudo foi desenvolvido sob uma abordagem comparativa descritiva, com a participação de 11 professores (5 de Matemática e 6 de Língua e Literatura). Para a recolha de dados, foi aplicado um questionário online aos professores e analisado através de tabelas comparativas das três dimensões do TPCK. Os resultados indicam que há mais provas de Conhecimento de Conteúdo Pedagógico Tecnológico em professores de Matemática do que em professores de Língua e Literatura. Conclui-se que há necessidade de apoiar os professores de ambas as disciplinas em áreas específicas da TPCK, a fim de melhorar as suas competências.
Palavras-chave: Conhecimento pedagógico tecnológico dos conteúdos; professor do ensino secundário, Matemática, Língua e Literatura

Introduction

Shulman (1986) opens the debate on what knowledge a teacher in any subject area should possess and proposes three general domains: content knowledge, pedagogical knowledge of content, and curricular knowledge. In support of this idea, Ball et al. (2008) indicate that teachers must have knowledge of the subject they teach, as a fundamental part of teaching competence, but they must also have the pedagogical knowledge to help students learn this content and also master the curriculum materials to plan teaching.

Ball et al. (2008) and Hill et al. (2005) particularize Shulman's (1986) study in mathematics and call it mathematical knowledge for teaching (MKT) and propose two general domains with three subdomains each (Figure 1):

Figure 1 – MKT model



Source: Ball et al. (2008, p. 403)

The MKT in studies with in-service teachers has been used as a professional development model in in-service training programs (e.g., STENDER ET AL., 2017), on the analysis of pedagogical content knowledge when planning lessons; Martínez et a. (2020), on the knowledge construction of multiple MKT components, through a variety of mathematical tasks).

On the other hand, the MKT has been adapted in research with student secondary mathematics teachers to assess the acquisition of teaching competences (e.g., SCHAEFER & SGRECCIA, 2018) to identify, describe and conceptualize Synthetic Geometry teaching practices; Graciano and Aké (2019) identify the knowledge of remarkable products of prospective mathematics teachers, through four subdomains of the MKT (CCK, SCK, KCS and KCT).

Carrillo-Yañez et al. (2018) particularized one of the domains proposed by Ball et al. (2008) MKT: specialized content knowledge (SMK) into specialized mathematics teacher knowledge (MSTK), in which they organize the MKT domains initially proposed by Ball et al. (2008). On the other hand, regarding new teaching competences and taking into account technological advances and the challenges that this brings for both teachers and students, Koehler et al. (2007) introduce a new theoretical model of teaching competences. These authors take Shulman's (1986) model, add the teacher's mastery of technologies, and call it

Technological Pedagogical Content Knowledge (TPCK), around which a good deal of research has been carried out.

Cenich et al. (2020) in a secondary school in Argentina, with 14 teachers who taught the subject of mathematics, investigated the knowledge and practice of some mathematics teachers in the implementation of technologies in the classroom. The results indicated that the TPCK allowed the characterization of mathematics teachers' practices and the way in which they integrate technologies into their teaching, coinciding with Osorio and Serrano (2022) in considering that this theoretical model offers an alternative for describing the professional development of mathematics teachers.

The TPCK has also been applied with prospective secondary mathematics teachers. Cabero et al. (2017) found that there is a high self-assessment of technological, pedagogical, and disciplinary knowledge by prospective teachers when each domain is considered separately but decreases when they are considered together. Also, Cabero et al. (2019) have used this model to validate teacher training in ICT.

In the existing literature, in most of the empirical studies that have been conducted under the TPCK theoretical model, the research subjects have been prospective teachers and in-service teachers of secondary mathematics, but not teachers of other subjects.

Therefore, the aim of this research is to analyze Technological Pedagogical Content Knowledge (TPCK) in teachers of Mathematics and Language and Literature subjects, Semester I, 2022.

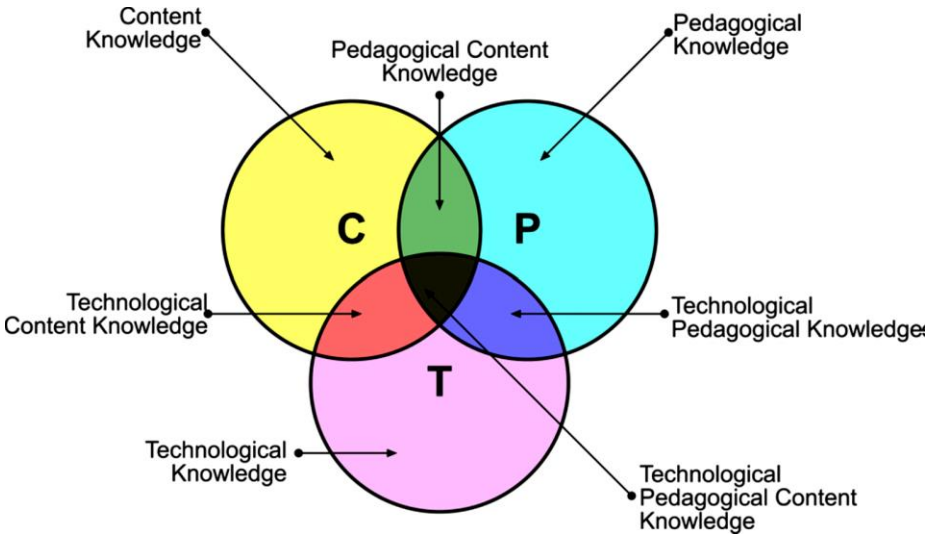
Theoretical framework

The TPCK model: teacher knowledge when integrating ICTs

Newer digital technologies, by nature, are versatile, unstable, and non-obvious and present new challenges to teachers who strive to incorporate them into their teaching (KOEHLER et al., 2007). Technology cannot be treated without context and good teaching requires an understanding of how technology is related to pedagogy and disciplinary content (KOEHLER et al., 2007). In the new model called TPCK (Technological Pedagogical and Content Knowledge), proposed by Koehler et al. (2007), technology is integrated into education from the point of view of teacher education and when the goal is to teach curricular content. The TPCK model results from the complex intersection of the three primary types of knowledge:

Content (CK), Pedagogical (PK), and Technological (TK). This knowledge is not only treated in isolation, but it is also addressed in the 4 intersecting spaces that generate their interrelationships: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technical Pedagogical Content Knowledge (TPCK) (Figure 2).

Figure 2 – TPCK model (KOEHLER et al., 2007, p.742).



Source: Koehler et al. (2007, p. 742).

For a teacher, effective integration of technology in teaching will result from a combination of knowledge of content, pedagogy and technology, but always taking into account the particular context in which it is applied. The different types of more complex knowledge would be:

Content Knowledge (CK)

The teacher must know and master the subject he/she intends to teach. The contents covered in environmental knowledge in primary school are different from those taught in natural sciences in secondary school or in geology at university. This knowledge includes concepts, principles, theories, ideas, conceptual maps, organizational schemes, points of view, etc.

Pedagogical knowledge (PK)

This refers to the knowledge of teaching and learning processes including, among others, general and specific objectives, assessment criteria, competences, organizational variables, etc. This generic form of knowledge applies to understanding how students learn, how to manage the classroom, how to plan lessons and how to assess students.

Technological knowledge (TK)

This refers to knowledge about the use of technological tools and resources including a general understanding of how to apply them productively to everyday work and life, the recognition that they can facilitate or hinder the achievement of a goal, and the ability to adapt and continually renew to new developments and versions.

Pedagogical Content Knowledge (PCK)

It focuses on the transformation of the subject matter to be taught that occurs when the teacher makes a particular interpretation of the content. There are several ways of presenting a subject and the teacher defines his or her own through a chain of decision-making where he or she adapts the teaching materials available, takes into account the students' prior knowledge, the curriculum, the general syllabus, his or her particular vision of assessment and pedagogy, etc.

Technological Content Knowledge (TCK)

This refers to the understanding of how technology and content influence and constrain each other. Teachers need not only to be proficient in the subject they teach, but also to have knowledge of how technologies can influence the presentation of content and, in addition, to know which specific technologies are best suited to address the teaching and learning of some content or other.

Technological Pedagogical Knowledge (TPK)

This refers to how teaching and learning can change when using different technological tools. This includes knowledge of the advantages and limitations of different technological tools to favor or limit one or other pedagogical strategies.

Technological Pedagogical Content Knowledge (TPCK)

Defines a meaningful and efficient way of teaching with technology that goes beyond the isolated knowledge of the different elements (Content, Pedagogy, and Technology) individually. It requires an understanding of the representation of concepts using technologies, of pedagogical techniques that use technologies constructively to teach content, of what makes

learning easy or difficult, of how technology can help solve students' problems, of how students learn using technologies, giving rise to new epistemologies of knowledge, or strengthening existing ones, and so on.

This research team has posed the following research question: What evidence of Technological Pedagogical Content Knowledge (TPCK) can we find in teachers of Mathematics and Language and Literature subjects?

Methodology

The present work was developed under a comparative descriptive approach because it seeks to identify the characteristics of the Technological Pedagogical Content Knowledge (TPCK) of the Mathematics and Language and Literature teachers at the secondary school under study. On the other hand, it is exploratory because the topic of study is relatively new and there is still a lot of research to be done, and cross-sectional because it was applied in the second semester 2022 (February - July). A questionnaire designed in Google Forms was applied, the link to which was sent to the participating teachers (5 in the area of Mathematics and 6 in Language and Literature) via WhatsApp, with prior permission from the school authorities. This questionnaire consisted of a first section of demographic and academic data of the teachers and a second section of three subsections with five items each and assessed the teachers' knowledge in the three domains of the TPCK (PCK, TCK, TPK).

The data collected were organized in an Excel spreadsheet for graphical representation of the first section; in the second section comparative tables were used with the mean values of the teachers' knowledge of each subject, in each of the items of the three domains of the TPCK. As each of the items were rated: 1=not at all, 2=not very much, 3=very much, then, in the tables we present the overall averages of the Mathematics and Language and Literature teachers in these items.

Results and discussion

Of the thirteen secondary school teachers in the study sample, 11 responded to the questionnaire (6 female and 5 male), 6 are from the subject of Language and Literature and 5 are from Mathematics, the ages range from 37 to 54 years old. It is worth mentioning that all

the teachers surveyed are graduates in the disciplines they teach, including one teacher with a Master's degree, as shown in Figure 3.

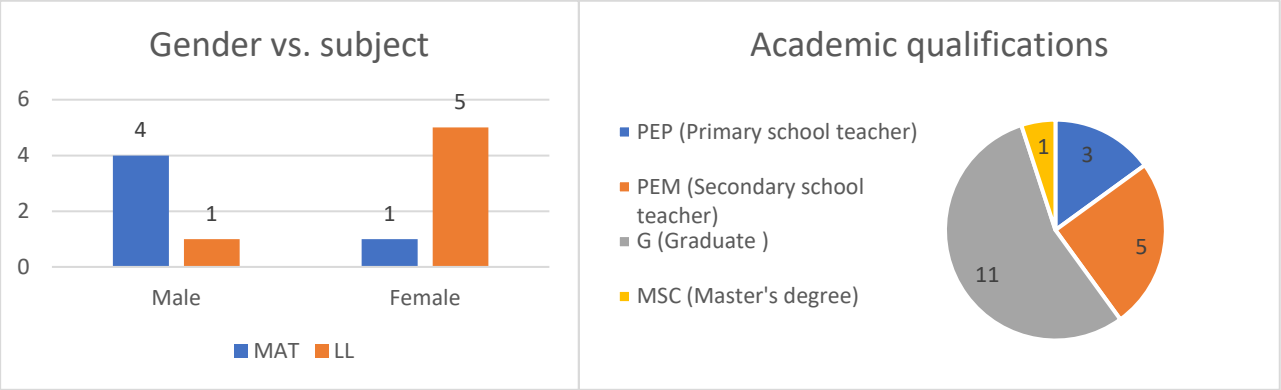


Figure 3 – Gender by subject and academic titles of the Mathematics and Language and Literature teachers who were the subjects of the study
Source: Authors

When asked about the technological applications they commonly use in the teaching and learning process of their subjects, the Language and Literature teachers mentioned the following Apps: Mimind, Youtube, Word, RAE, Audio Books, Classroom, ABC, while the mathematics teachers used: GeoGebra, PowerPoint, YouTube, Mathlab Graphing Calculator, Mathway, and Photomath. There is evidence of constant training courses in the use of technology by Mathematics teachers and also that most of them are graduates of the degree in Educational Sciences, with a specialization in Educational Mathematics and Computers, offered by the University of Nicaragua, a degree course that trains future teachers by combining mathematical and technological knowledge.

Results on Pedagogical Content Knowledge (PCK)

Table 1 shows the averages for each of the items of Pedagogical Content Knowledge (PCK), which the teachers assessed as follows: 2ai) I have excellent knowledge of the content I teach; 2aii) I feel comfortable teaching any curriculum content of the subject I teach; 2aiii) I have many strategies to apply in teaching the curriculum content; 2aiv) I know the didactic sequence of the content of my subject in each grade of secondary education; and 2av) I have the ability to help my colleagues to better understand how to teach some content.

About this knowledge, it can be observed, in global terms, that Mathematics teachers consider that they have a lot of Pedagogical Knowledge of the mathematical contents they teach

in their classrooms, while Language and Literature teachers consider that they have little knowledge. However, it is also evident in both subjects that teachers need help in teaching strategies to apply them to the content of the curriculum and to strengthen their ability to help their colleagues understand how to teach certain content.

Table 1 – Pedagogical content knowledge of Mathematics and Language and Literature teachers, subjects of the study

Subjects	**Pedagogical content knowledge**					
	2ai	**2aii**	**2aiii**	**2aiv**	**2av**	**PCK**
LL	2	2	2.17	2	2	2.03
MAT	2.8	3	2.6	2.8	2.6	2.76

Source: Authors

Results on Technological Content Knowledge (TCK)

Table 2 shows the averages in each of the items of the Technological Knowledge of Content (TCK), which assessed teachers as follows: 2bi) I know the technologies that the curriculum suggests to apply them in the teaching of my subject; 2bii) I have applied most of the technologies that the curriculum of my subject suggests to me; 2biii) I have used other technologies that are not suggested in the curriculum; 2biv) I know how to evaluate which technological applications help to better understand the contents; and 2bv) I know how to evaluate students' learning through the use of technologies.

With respect to this knowledge, it can be observed, in global terms, that both Mathematics and Language and Literature teachers consider that they have little Technological Knowledge of the Contents they teach in their classrooms; however, the evidence suggests that Mathematics teachers have more knowledge than Language and Literature teachers about the knowledge of the technologies that the curriculum suggests to apply them in the teaching of the subject, to evaluate which technological applications help to better understand the contents and to evaluate student learning through the use of technologies.

Table 2 – Technological Content Knowledge of the Mathematics and Language and Literature teachers studied

Subjects	Technological Content Knowledge					
	2bi	**2bii**	**2biii**	**2biv**	**2bv**	**TCK**
LL	2	1.83	2.17	1.83	1.83	1.9
MAT	2.6	2	2.2	2.8	2.6	2.44

Source: Authors

Results on Technological Pedagogical Knowledge (TPK)

Table 3 shows the averages for each of the Technological Pedagogical Knowledge (TPK) items, which assessed teachers as follows: 2ci) I can use the Office package and web search as tools for planning; 2cii) I can create virtual spaces to teach my students; 2ciii) I can select technologies that enhance teaching approaches for a lesson; 2civ) I can guide my students in using a technological application; and 2cv) I am able to help my colleagues in the use of technologies.

With respect to this knowledge, it can be observed, in global terms, that Mathematics teachers consider that they have a lot of Technological Pedagogical Knowledge to support their teaching work, while Language and Literature teachers consider that they have little. However, both Mathematics and Language and Literature teachers need support in the use of the Office package and web search as tools for planning and creating virtual spaces to teach their students.

Table 3 – Technological Pedagogical Knowledge of the Mathematics and Language and Literature teachers studied

Subjects	Technological Pedagogical Knowledge					
	2ci	**2cii**	**2ciii**	**2civ**	**2cv**	**TPK**
LL	2	2.17	2	2.17	2.2	2.1
MAT	2.4	2	2.6	2.6	2.6	2.56

Source: Authors

Results for Technological Pedagogical Content Knowledge (TPCK)

Finally, Table 4 shows the overall comparative results of Technological Pedagogical Content Knowledge (TPCK), as an average of the three dimensions (PCK, TCK and TPK).

Overall, the evidence suggests that Mathematics teachers have high levels of Pedagogical Technological Content Knowledge for teaching, while Language and Literature teachers have low levels. However, it can be noted that in both subjects Technological Content Knowledge (TCK) is the lowest and that it sheds light on the needs in which teachers need to be supported.

Table 4 – Pedagogical Technological Content Knowledge of the Mathematics and Language and Literature teachers studied

Subjects	**Pedagogical Technological Content Knowledg**					
	PCK	TCK	TPK	TPCK	PCK	TCK
LL	2.03	1.9	2.1	2.01	2.03	1.9
MAT	2.76	2.44	2.56	2.59	2.76	2.44

Source: Authors

Conclusions

The aim of this research was to analyze the Technological Pedagogical Content Knowledge (TPCK) of teachers of Mathematics and Language and Literature in a secondary school in Nicaragua in the first semester, 2022. The results suggest that Technological Pedagogical Content Knowledge (TPCK) in Mathematics teachers is more evident than in Language and Literature teachers.

Mathematics teachers show more evidence of high Pedagogical Content Knowledge (PCK) and Technological Pedagogical Content Knowledge (TPK), but show evidence of the need for further support in Technological Content Knowledge (TCK), especially in the use of the technological applications suggested by the curriculum and in the use of others not suggested by the curriculum, despite the fact that most of them are graduates of the Bachelor's Degree in Educational Sciences, specializing in Educational Mathematics and Computer Science, and that they have participated in ongoing professional development training for teachers. On the other hand, teachers of Language and Literature have shown evidence of low content knowledge in the three dimensions of the TPCK, which suggests that they need more support in these domains of knowledge to be able to perform the teaching functions required for the teaching and learning of the subject.

In conclusion, it can be said that the theoretical model of Technological Pedagogical Content Knowledge (TPCK) is a tool that can be used to assess teachers' professional

development (CABERO et al., 2019; OSORIO & SERRANO, 2022), allowing the identification of strengths and limitations in the three dimensions of teachers' knowledge, with which educational organizations can make decisions about future training to improve teachers' skills.

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Autores

Domingo Felipe Aráuz Chévez
Assistant Professor of Research Methodology from the National Autonomous University of Nicaragua, León.
Master in Comparative Education from the National Autonomous University of Nicaragua, León.
PhD Candidate in Educational Research at the University of Alicante-Spain.
National Autonomous University of Nicaragua-León (UNAN-León)
domingo.arauz@fh.unanleon.edu.ni
https://orcid.org/0000-0003-2915-1198

Martha Teresa Chavarría Guido
English Language Instructor from the National Autonomous University of Nicaragua, León. Master in English Teaching as a Foreign Language with University of Alcalá de Henares, Spain.
Doctor in Education with emphasis on Pedagogical Mediation with University of La Salle, Costa Rica.
National Autonomous University of Nicaragua-León (UNAN-León)
marthachavarria@fh.unanleon.edu.ni
https://orcid.org/0000-0001-5675-9997

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Anexos

Questionnaire applied to Mathematics and Language and Literature teachers.

Variable	concept definition	Dimension	subdimension	Worth	Instrument
Sociodemographic data	Demographic data is general information about groups of people	**1st personal**	Sex	M:___ F:___	**Questionnaire**
			Age	open	
		1 B. academics	years of work	open	
			Title (More than one)	PEP: PEM: Graduate: MSc:	
			Mention technological applications or software that you have ever used in teaching	open	
Technological Pedagogical Content Knowledge (TPCK)	**1. Not at all 2. Little 3. A lot**				
	Theoretical framework on the close relationship that exists between technological, pedagogical knowledge and the content to be taught by teachers	**2nd Pedagogical Content Knowledge (PCK)**	2.ai. I have excellent knowledge of the content I teach.	1. 2. 3.	**Questionnaire**
			2.ai. I feel comfortable teaching any content of the curriculum of the subject I teach.	1. 2. 3.	
			2.aiii. I have many strategies to apply in teaching the contents of the curriculum.	1. 2. 3.	
			2.aiv. I know the didactic sequence of the contents of my subject in each grade of secondary education.	1. 2. 3.	
			2.av. I have the ability to help my classmates better understand how to teach some content.	1. 2. 3.	
		2.b. Technological Content Knowledge (TCK)	2bi. I know the technologies that the curriculum suggests applying them in the teaching of my subject.	1. 2 3.	**Questionnaire**
			2bii. I have applied most of the technologies that the curriculum of my subject suggests.	1. 2. 3.	
			2biii. I have used other technologies that are not suggested in the curriculum.	1. 2. 3.	
			2biv. I know how to evaluate which technological applications help to better understand the contents.	1. 2. 3.	
			2biv. Student learning is evaluated through the use of technologies	1. 2. 3.	
		2 C. Technological Pedagogical Knowledge (TPK)	2ci. I know how to use office suite, web search as tools for planning.	1. 2. 3.	**Questionnaire**
			2cii. I can create virtual spaces to teach my students.	1. 2. 3.	
			2ciii. I know how to select technologies that improve teaching approaches for a lesson.	1. 2. 3.	
			2civ. I know how to guide my students in the use of a technological application.	1. 2. 3.	
			2cv. I am able to help my classmates in the use of technologies.	1. 2. 3	