Research Article

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Mathematics Teachers' TPACK Development Based on an Online Course with Geogebra

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Abstract: This paper aims to discuss the Technological Pedagogical Content Knowledge (TPACK) development by mathematics teachers (preservice and inservice) that participated in an online course for developing educational apps and puzzles with GeoGebra. Theoretical foundations are based on the authors Punya Mishra, Matthew J. Koehler et al, regarding TPACK framework and Margaret Niess et al regarding the development of TPACK by mathematics teachers. The research method is qualitative, and to analyze the thoughts and ideas discussed by the participants, we used the Discursive Textual Analysis. In this regard, three representative categories were used to build the following metatexts: instructional approaches, classroom environment management and teacher's professional development. Through the Discursive Textual Analysis, it was possible to understand the participants concerns in creating different instructional approaches using Information and Communication Technologies, once they realized that dealing with digital natives requires pedagogical innovations, supported by new technologies, and new ways to configure and manage classroom environments permeated by digital resources.

Keywords: TPACK, Teacher Training, Information and Communication Technologies, Discursive Textual Analysis.

1 Introduction

The contemporary youth, often described as digital natives, were raised with continuous access to personal computers, tablets and smartphones that can be connected to the internet, which allows interaction, in real time, with other people, news, opinions, statistics, etc. In other words, students have, nowadays, free access to an uncountable amount of information posted online every single day (Prensky, 2001). When digital natives interact in educational environments they tend to behave as active questioners and researchers, not as mere data receivers, in terms of education content such as historic facts, formulas, states and their capitals. This hierarchy rupture represented by the access to information and, consequently, the ways in which formal education is understood impacts directly the teacher's activities and requires urgent changes (Kenski, 2012).

In order to understand how digital natives think, teachers should review teaching and learning methods. Therefore, pedagogical interactions should be less step by step, which means less linear, and should be developed more through multiple access, shared creations, random searches, researches, among others particularities included in Information and Communication Technologies (ICT) and with the youth way of living in the 21st century (Prensky, 2001). Ketelhut (2019) argues that many materials and methodological approaches used by teachers continue to be the same used in the middle of the 20th century and this fact will not prepare the students to engage properly in the contemporary world.

According to Oliveira, Henriques and Gutiérrez-Fallas (2018), it is important that teachers' professional development courses provide teachers (preservice and inservice) with opportunities to incorporate ICT in teaching and learning processes. Thus, it is assumed by Mishra and Koehler (2006) that meaningful formative interaction provides teachers with opportunities to understand the relationships comprising content, pedagogy and technology, which leads to Technological Pedagogical Content Knowledge (TPACK), conceptualized

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by the authors as “an emergent form of knowledge that goes beyond all three components (content, pedagogy and technology)” (p. 1028).

In this context, this research analyses an experience with participants of an online teachers' training course, based on the TPACK framework. The course used GeoGebra as a primary tool and the course was designed by one of the authors in this paper. This study aims to understand the perceptions of the students regarding their progress in terms of knowledge on the integration of ICT in their classes, according to the TPACK framework.

2 Theoretical Framework

Shulman (1986) introduced the idea of Pedagogical Content Knowledge (PCK) arguing that subject knowledge and pedagogical knowledge are not mutually exclusive aspects of teachers' work. In this perspective, he proposed the idea that PCK “goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching” (p. 9).

Different kinds of knowledge began to be required for teachers since the ICT incorporation in the lives of most world citizens. Therefore, Mishra and Koehler (2006) created Technological Pedagogical Content Knowledge (TPACK), which is based on Shulman's (1986) conceptualization, adding a third dimension that encapsulates ICT.

TPACK framework, as Mishra (2019) explains, describes the kinds of knowledge that enable contemporary teachers to integrate new technologies into the 21st century educational scenario. In this regard, “effective teaching depends on flexible access to rich, well-organized, and integrated knowledge from different domains, including knowledge of student thinking and learning; knowledge of the subject matter; and, increasingly, knowledge of technology” (Koehler, Mishra & Cain, 2013, p. 13).

Therefore, ICT is understood as playing an important role in educational contexts to create analogies, illustrations, examples, and demonstrations that could make some topics more accessible for the students. Accordingly, Cejas-Léon and Navío-Gámez (2020) argue that contemporary teachers cannot be limited to learning only technical abilities on the operation of available digital tools, instead, they should get use to continuous adaptation, so developing abilities to follow the changes since ICT are constantly renewed.

Niess *et al.* (2009) states that once technology, students, teachers and educational contexts change,

Figure 1: The three integrated dimensions representing the TPACK framework.

Source: Mishra (2019).

TPACK provides a dynamic theory to support the comprehension towards what kinds of teaching knowledge are necessary for the curriculum development as well as teaching practices concerned in helping students to think and learn through the ICT support. According to Cibotto and Oliveira (2017), the perception about the context that influence on pedagogical interactions is a fundamental part of TPACK, as observed in Figure 1.

Considering the relevance of the educational environment, Mishra (2019) presents the idea of Contextual Knowledge (XK), described as the teachers' knowledge on the conditions in which their practices occur. More specifically, the author points out that the XK includes information from the perception about the ICT available at the school, and incorporating the knowledge regarding the teaching institution, the neighborhood, the city, the state. Thus, “many approaches to teachers' professional development offer a one-size-fits-all approach to technology integration when, in fact, teachers operate in diverse contexts of teaching and learning” (Koehler, Mishra & Cain, 2013, p.14).

TPACK is considered by Mishra and Koehler (2006) as an essential part into the development of good teaching practices with ICT. In this regard, Koehler, Mishra and Cain (2013) emphasize the importance of comprehending: different possibilities of representations allowed by the

ICT; pedagogical techniques using digital technologies; distinction of what makes a concept easy or difficult and how the ICT can be useful to solve these problems; awareness of the students' previous knowledge; and how the ICT can be used to build new epistemologies or to develop those that already exist.

Considering the TPACK framework, Cejas-Léon and Navío-Gámez (2020) argue that teacher training to incorporate ICT into educational practices requires a different approach. This claim is relevant because as with the innovations proposed by Shulman (1986), when there was a dichotomy between pedagogical knowledge and subject matter knowledge, nowadays there still “exists a tendency to focus the attention more on the technology as a tool than in the way it can be used to teach important ideas” (Oliveira, Henriques & Gutiérrez-Fallas, 2018, p. 423).

When learning about new technology, Kettelhut (2019, p. 21) explains that this knowledge is “assimilated into the existing mental frameworks or those frameworks must be forced into disequilibrium until accommodation is reached, creating a new TPACK for that teacher”. Accordingly, Oliveira, Henriques and Gutiérrez-Fallas (2018) state that TPACK emerges when comprehension about the ICT expands and creates an intersection with pedagogical content. Mishra and Koehler (2006) propose that, from the TPACK framework, it is possible to emphasize connections, interactions and limitations related to subject matter, pedagogy and technology, which are essential elements for the development of good teaching practices.

The TPACK framework has been used in research, teaching and learning practices as well as in professional teachers' development training, as outlined by Mishra (2019). In line with this perspective, Oliveira, Henriques and Gutiérrez-Fallas (2018) state that the knowledge regarding TPACK has been used as a theoretical basis for studying the initial and continuous teachers' training. Moreover, it has been used to investigate how this knowledge is developed and integrated with ICT into the teachers' classes.

3 TPACK in Mathematics Education

According to Niess *et al.* (2009), studies carried out with teachers in activity suggest different levels of digital technologies integration in Mathematics classes. Therefore, it is important to investigate how the TPACK is developed and how teachers, in both cases, those who have work experience and those who are beginning

training, may evolve in this matter. Thus, the authors propose a TPACK's developing model, which is divided into five stages. This model aims to translate how Mathematics teachers learn to integrate ICT into their teaching practices, according to the following description.

Recognizing – It is defined when teachers seem to be ready to use the ICT and recognize their alignment with different mathematical contents, however, they cannot integrate digital technologies into teaching and learning processes. The reason why this behavior happens is because they are usually concerned about the time the students take to understand ICT. Consequently, they end up using technological tools only to reinforce ideas already studied through other methods. Regarding professional development, teachers have been considering training courses to learn more about ICT.

Accepting – It is noticeable when teachers develop a favorable attitude towards the use of appropriate digital technologies to teach and learn Mathematics. These educators begin to use ICT at the end of the subject matter units, in classes in which new concepts are not studied by students or in complementary activities. Searching for developing new mathematical ideas, they begin to apply simple practices permeated by ICT. Since they are still insecure about it, they try to control the students by orchestrating their actions while they are using new technologies. When including digital tools in class, the teachers realize the need to improve their knowledge in this area, which takes them to start looking for training courses which include this approach.

Adapting – This stage is identified when teachers begin to plan lessons that adapt teaching and learning practices using ICT. Digital technologies are used to reinforce or improve mathematical contents that have previously been worked in class. Simple practices are introduced with ICT but adapting those activities to the class. Teaching strategies are mostly teacher centered to maintain control on the class progress. Of concern to their professional development, teachers learn and explore new ideas for Mathematical Education, yet still are using only one kind of software.

Exploring – It is noticeable when Mathematics teachers constantly integrate teaching and learning practices with appropriate technological resources. They begin to involve their students in more sophisticated activities, such as problem solving or mathematical investigation in class, using ICT as significant learning resources. Thus, these teachers become interaction mediators and tend to use different teaching strategies, permeated by different kinds of ICT tools. They begin to interact with other teachers to investigate the curriculum in order to find enriching ways

Figure 2: Visual description of the TPACK development.

Source: The authors (available at: <https://www.geogebra.org/m/dxa2erhf>).

of integrating appropriated ICT into teaching and learning practices.

Advancing – This stage is characterized by using ICT to facilitate mathematical ideas for the students as well as by a critical analysis of the results from introducing digital technologies into the Mathematics class. At this stage, teachers begin to adapt a variety of methodologies using ICT to stimulate the students to think and understand Mathematics. They coordinate teaching activities with a strong presence of digital technologies, seeking to keep the students' engagement and encouraging their autonomy for building knowledge. Regarding their professional development, they are constantly looking for new opportunities to learn about the integration of ICT into Mathematics education and to explore pedagogical ideas involving multiple technologies.

Therefore, it is possible to conclude that TPACK is gradually developed and the transition from a level to another is not configured in a regular way or through a consistent growing pattern (Niess *et al.*, 2009). Thus, the

diagram shown in Figure 2 illustrates a representation for the development of TPACK. In this model, a converging 3D spiral highlights how Technology, Pedagogy and Content come closer as the development path passes through different stages. In addition, the spiral movement suggests a crucial idea of passing through proximal zones repeatedly along the pathway, as a sewing process. The dynamic representation still allows a slight adjustment regarding the distance between each two stages. This mobility means that the stages do not necessarily need to be equally distant from each other, i.e., two stages can be more connected and more distant to the next. This fact implies that there might be different timing for each person to develop in each stage.

Based on these five sequential stages of the TPACK development, and aiming to investigate its evolution with Mathematics teachers, four interesting aspects of teaching practice concerning this framework were described by Niess *et al.* (2009): *Curriculum and Evaluation*; *Learning*; *Teaching*; and *Access*.

The focus of this investigation is on the *Teaching* dimension, which is concerned with instructional approaches, classroom environment management and professional teaching development. This choice is due to the fact that the course includes pre-service teachers, who are not acquainted with specific practical elements of classroom interaction with ICT.

4 Methodology

The explorative nature of the study required an interpretative approach, comprising qualitative methods (Cohen, Manion, & Morrison, 2011). The professional development course was carried out from May to July 2020, through online interactions (described below). This course was offered by the Federal Institute of Education, Science and Technology of Rio Grande do Sul¹, in Brazil, for 30 participants, who developed all the activities in the Moodle and GeoGebra platforms. At the end, 19 participants completed the course and 10 answered a questionnaire. The questionnaire answers were analyzed in the scope of Discursive Textual Analysis (DTA²), proposed by Moraes & Galiuzzi (2007).

4.1 A Course Description Through TPACK's Lenses

In line with the stages proposed by Niess *et al.* (2009), the course “Development of Apps and Digital Logic Games with GeoGebra” (40h) was offered over 6 weeks in distance learning mode. The main objective was sharing resources and possibilities (technological knowledge using GeoGebra) with experienced and beginner teachers to encourage them to develop more interactive digital materials that could enhance users’ motivation and autonomy. In addition, the course intended to provide pedagogical experiences aiming at promoting critical thinking, having mathematical development as a mean and not necessarily as an end activity. For these reasons, and because of the attractive appeal that games and logical challenges usually have among students, the course was structured in four stages, which are presented below³.

FOLLOWING (1st week) – In this first level, which comprises the *Recognizing* and *Accepting* stages, the participants were introduced to an initial activity for some ideas on modeling a sliding puzzle⁴ as a warm up mathematical discussion as part of the process of playing or interacting with it. In addition, this level was a first approach in encouraging the participants to become acquainted with some Boolean logic syntaxes, which would later help them to develop their own materials. As a guided task, a series of tutorial materials was available to support the participants in reproducing the puzzle, or even personalize their own puzzle. Combinatorics, parity problem and lowest common multiple (LCM) were some of the topics that came up during this stage.

ADAPTING (2nd week) – Following the *Adapting* stage proposed by Niess *et al.* (2009), this level was crucial to engage participants with the use of some GeoGebra features, either from a technological or a pedagogical point of view. Particularly, the development of digital materials in this stage was triggered by small pedagogical changes of selected materials (this fact did not mean a minor task – it was quite challenging in fact). For instance, splitting an activity that had originally six geometrical problems at once into different phases. The intention was to promote the use of different GeoGebra interactive features, such as sliders, checking boxes or buttons. Another example was changing the original geometrical shape in a task to analyze the mathematical implications of it and how the code behind could be used in that sense.

PLANNING (3rd week) – This level looks at the importance of *exploring* existing materials to identify possibilities for integrating them as pedagogical sources in line with their teaching demands and interests. GeoGebra is an online platform which allows all users to freely copy, distribute and share its materials for non-commercial purposes. Thus, the idea was encouraging the participants to find materials that could be used for their own teaching experiences, even though a few adjustments might be necessary. Therefore, the participants were instructed to choose a material and formulate questions related to it as well as to identify how that specific material could be introduced in the Brazilian National Curriculum. This activity was conducted in small groups, in which the participants were encouraged to share their ideas and support each other.

CREATING (4th, 5th and 6th weeks) – The last level of the course aimed at promoting creative actions based on the previous levels as well as brainstorming sessions with the

¹ Better known as IFRS, the institution offers Vocational Courses (high school level) and Mathematics Teacher Training Program, among other undergraduate and postgraduate courses.

² In Portuguese, the acronym DTA is better known as ATD since the literal translation is “Análise Textual Discursiva”.

³ The italic terms refer to the TPACK's developing model stages.

⁴ The puzzle activity is based on this workshop: <https://www.geogebra.org/m/qgqrneys>.

participants during online meetings and through forum discussions. This level was conceived to be aligned to the *Advancing* stage, in which, according to Niess *et al.* (2009), teachers assess the results of their decisions to integrate teaching and learning Mathematics with appropriate technology. Accordingly, the participants considered both the subject matter and the pedagogical approach in relation to the use of games or logical challenges. The final productions revealed that the participants were able to integrate interactive GeoGebra features in different game contexts, covering a variety of mathematical topics.

In addition to the Moodle and GeoGebra platforms, the course also included synchronous meetings (at least one per week) via Google Meet⁵, which were recorded and then shared with all participants. Thus, the discussion could be extended asynchronously in the event of missing any meeting. Analyzing to what extent the course has contributed to mutual collaboration is not in the scope of this study. Nevertheless, considering the knowledge exchanges and experiences among the participants (not only quantitative, but mostly qualitative), this experience cannot be described as a short course, as suggested by Weinhandl, Lavicza & Houghton (2020, p. 318).

Furthermore, these authors state that the knowledge of participating teachers should be assumed as a promising basis for teacher professional development courses. Thus, everyone would benefit from exchanging knowledge and competencies. An example from the course that illustrates this fact is a quick video tutorial recorded by one of the participants to support a colleague who was struggling in the first level. It was a clear win-win situation since, on the one hand, this episode encouraged the assisted participant to progress and successfully conclude the course. On the other hand, the assistant participant developed an appropriate pedagogical strategy, increasing her skills on video editing.

4.2 Strategies to a Discursive Textual Analysis

Aiming to analyze the participants' perceptions regarding how the knowledge acquired during the course could be applied in their Mathematics classes, they were asked to answer a short questionnaire, from which this particular study focused on two questions: "How do you plan to continue learning about ICT integration in Mathematics

classes?" and "How do you comprise the role of Mathematics Teachers on a pedagogical interaction using new technologies?".

All responses were analyzed using DTA (Moraes & Galiuzzi, 2007). The texts resulted from the following sequence: unitarization, categorization and metatexts creation. The first phase involved turning the texts into smaller fragments, named as sense units.

In the second phase, the sense units were grouped according to similarity of ideas. The categorization, as pointed out by Moraes & Galiuzzi (2007), is a process of creation, ordering, organization, and synthesis.

The final stage consists in the communicating the texts analysis. As a result, descriptive and interpretative texts are built, coming from connections and relations developed during the categorization process. Therefore, each metatext was created using fragments of the subjects' narratives, analysis, and interpretations from the researchers and the approached theoretical scope.

5 Results and Discussions

As explained in the previous section, the participants' responses were analyzed through the DTA process and three metatexts were created according to *Teaching* dimension, focusing on instructional approaches, on learning environment management and on teacher professional development (Niess *et al.*, 2009). The metatexts corresponding to each of these components are presented below⁶.

5.1 Instructional Approaches

The participants' responses showed that discussions and analysis about instructional approaches had been highlighted by them. In this context, P8 asserted that he has "interest in learning new ways of presenting concepts and subject matters" and P9 highlights that he is planning to "create more pedagogical material and ways of teaching using ICT".

While P5 said he would try to improve her/his classes "with games and apps", others, such as P2 and P10, manifested their intentions to develop projects with their students using digital resources. It is also necessary, according to P6, "to provide teachers (pre-

⁵ Google Meet is a free video conferencing software, offered as part of G Suite and to free Google users. Meet offers features like real-time captions and support for up to 250 participants.

⁶ Aiming to preserve the identity of the participants, they are identified as: P1, P2, ..., P10.

Figure 3: Finding bones.

Source: <https://www.geogebra.org/m/drmtqcv7>.

service and in-service) with opportunities for developing mathematical learning objects and games by using GeoGebra platform” and, as suggested by P7, to give them “freedom to create and evolve”. These ideas are in line with Mishra and Koehler (2006), since they argue teaching is a highly complex activity and each teacher is part of a unique work context.

While some participants presented skills related to the first stages of integrating ICT to Mathematics classes, others seem to be at more advanced levels, as described by Niels *et al.* (2009). However, according to Oliveira, Henriques and Gutiérrez-Fallas (2018) introducing technological resources into teaching practice just as a complimentary item cannot be considered satisfactory. It is considered substantial, therefore, that the educator does not give up on experiencing distinct instructional pedagogical approaches using ICT to improve their teaching practice, aiming at methodological plurality. In this regard, P8 recognized that “the variety of approaches studied is positive for the teaching-learning process”.

The participant P8 also states that “new technologies are important, and they are great tools for teaching and learning” and he “believes they are a very versatile and adaptable way to improve pedagogical interaction in class”. Likewise, P9 emphasizes that “it is always

important to establish the purpose of a game or any didactic tool in order to make it really useful for learning and not just something random in a lesson”. Accordingly, Mishra and Koehler (2006) argue that technology can restrict action or increase possibilities in terms of teaching and these effects should be considered by teachers on their pedagogical decisions.

In fact, according to Mishra (2019), planning and applying distinct instructional approaches using ICT require awareness on the students and teachers’ roles towards the subject matter, pedagogy, and technology. An example that illustrates a possible methodological approach for introducing the Cartesian coordinate system is presented in Figure 3. This idea proposed by one of the participants, illustrates how to unify pedagogical (game) with the subject matter (Cartesian coordinate system) and technology (applet). From an existing material (available in [geogebra.org](https://www.geogebra.org/m/drmtqcv7)), the participant improved it significantly and created her own game, which goal consists in getting a dog to find as many hidden bones as possible, in 90 seconds. To achieve it, the player must move the dog to the indicated points (indicated on the right side) in the Cartesian plane and push the “digging” button to find the bones. Based on this, students are practicing the corresponding inputs in the ordered pair. Whenever the dog catches a bone, a new goal is offered. In the image

below, the instructions were translated to English to exemplify how the applet works.

It is important to emphasize that the quick feedback provided by the activity is a factor that contributes positively to the dynamism and the players' (students) engagement in the class. This suggestion could be applied as a challenge for students, contributing for gamification ideas as an option of instructional approach. The gamification and layout adaptations reflect the ConteXtual Knowledge (XK) outlined previously, since the participant conceived this activity targeting a certain group of students. Creating a pedagogical game corroborates the idea suggested by Weinhandl, Lavicza & Houghton (2020), that by using new pedagogical approaches, teachers who participate in online courses become real knowledge developers.

5.2 Classroom Environment Management

Besides instructional approaches, teachers must consider the classroom environment management since they are responsible for teaching and observing the learning processes of their students. One way to complement and improve teachers' knowledge in this context, according to P1, is "to comprehend that the teacher is not the only one who knows and that he can learn from the students as well". Similarly, P4 suggests that through his career, the teacher "keeps exchanging experiences with other colleagues".

Weinhandl, Lavicza & Houghton (2020) emphasize that one alternative to enrich the teachers' professional development consists of sharing knowledge and materials with their peers, and online courses enable this exchange. Formative experiences, according to Oliveira, Henriques & Gutiérrez-Fallas (2018), as discussed in this study, are opportunities for teachers to upgrade their TPACK.

Another participant, P5, claims that teachers, when managing pedagogical interactions between (and among) students, "also need to know how to use the technologies in class" since, as highlighted by P2, "everyone is inserted in the technological world, including teachers and students". This participant adds that, in face of the unique context of the year 2020, characterized by social distancing due to the pandemic COVID-19, "it is extremely important to associate the use of technology to pedagogical practices".

According to Cejas-Léon and Navío-Gómez (2020), however, there still exist teachers that do not feel comfortable in changing their practices. In this regard, technological tools demanded as part of their

work routine might cause apprehension and concern. Therefore, Oliveira, Henriques & Gutiérrez-Fallas (2018) argue that, realizing the relevance of the TPACK as a necessary knowledge for teachers who work with digital natives demands figuring out ways to engage mathematics teachers in activities that provide them experiences integrating technology with mathematical concepts and pedagogical approaches.

Managing a classroom environment in which students are digital natives requires innovative behavior from the teacher. Since ICT is a current reality, access to information, interactional processes and communication has been going through constant changes. According to P2, "the teacher's role is to introduce, mediate and provide the students with learning through technology". Likewise, participants P3, P5, P6 and P10 stress that teachers must be mediators and P6 adds that, moreover, it is relevant that teachers become "encouragers for knowledge construction".

It is no longer valid to state that traditional teaching practices, which apparently have always worked, will keep on succeeding with the digital natives. Thus, classroom environment management demands a detachment from outdated practices and attitudes, because if the "teachers really want to reach digital natives – I mean, all their students – they will have to change" (Prensky, 2001, p. 6).

5.3 Teacher Professional Development

When the topic was teacher training, all the participants stressed the relevance of a constant professional development, sharing experiences with colleagues and being open to new ideas. One of the participants, P1, said that teachers "must be open to new possibilities and must be proactive". Likewise, P4 states that educators should be "willing to study and learn more about using new technologies".

Although the initial training promotes the investigative work, teachers must, according to P4, be aware of perceiving their role as "researchers", because a teaching degree alone is not enough to guarantee a qualified updated professional knowledge. In this regard, Ketelhut (2019) claims that universities can hardly follow the speed of technological changes in the world and this effect has an impact on teachers' training. For this reason, it is not rare to find teachers feeling unprepared to using ICT in their classes (Koehler, Mishra & Cain, 2013).

Searching for courses to complement and broaden the teachers' knowledge should be a constant action.. Concerning this, the participants stated how they intended

to continue their studies: “from training and research in this area” (P1), “through qualification courses, studies and continuous training” (P2), “through courses which are complementary to my teaching degree” (P3), “by participating in training courses” (P4) and “participating in other courses to improve domain on this theme” (P6). For P7 “the training process is continuous”, then he “intends to participate in as many courses as possible”. Regarding online teachers’ training, Weinhandl, Lavicza & Houghton (2020) point out that there are research findings that present promising results on pedagogical content knowledge development, which is a key aspect to improve TPACK.

Knowing about the current global connections, the available online resources can be a great option to enrich teachers’ knowledge, since they offer a great variety of options for everyone in just one click. Through digital tools, P4 has been improving his knowledge by “watching videos available online”, while P9 reports that, with the same goal, he is enrolled in “courses about software to be able to create games or digital didactic materials”.

It is then considered that the arguments given by the participants show their concerns about searching complementary training for developing knowledge so they can be more prepared to use distinct instructional approaches in their classes. The participants also underline that, in face of the contemporary technological reality in which the digital natives live, it is crucial to know when and how using ICT in teaching and learning practices. Thus, they revealed that the “Applications and Logical-digital Games Development with GeoGebra” course provided not only learning about some digital tools, but also the development of competences considered important to improve their TPACK.

6 Conclusion

This paper described the stages of a 40 hours online course for the development of digital puzzles and applicative through GeoGebra. This course, targeting (preservice and inservice) teachers, was structured according to the five sequential levels model of ICT integration in the Mathematics Education proposed by Niess *et al.* (2009).

Unlike most of the teachers’ training courses, regarding ICT, which focus mainly on learning abilities to work with technological tools, this particular course aimed to be different, based on the theories proposed by the following authors: Mishra & Koehler (2006), Oliveira, Henriques & Gutiérrez-Fallas (2018) and Cejas-Léon & Navío-Gámez (2020). Therefore, the course was carefully

designed to provide opportunities to share and promote sources of inspiration, ideas and possibilities in favor of the importance of ICT for developing mathematical thinking as part of the learning process and not only as the final result of it.

The analysis evidenced the participants’ concerns in providing students with different instructional approaches using ICT, since they realized that teaching digital natives requires pedagogical innovations as well as new ways to conceive and manage classroom environments. These perceptions reveal the need for constant professional development, as mentioned several times, this experience led the participants to becoming, each week of the course, more and more familiar and confident in using digital resources to enrich their pedagogical strategies with new technologies.

The participants’ progress on the TPACK development along the course was gradually noticed. It is important to point out that this progress was not limited to the use of GeoGebra tools, reaching other dimensions of teaching such as planning and applying activities using ICT and focusing on students’ learning. Therefore, the analysis showed that the participants increased attention in trying to relate technology, pedagogy, and subject matter.

The course represents one action among many other possibilities to assist teachers in developing their knowledge concerning the role of technology into teaching and learning processes. Following the argument that, being aware of the fast changes lived by the global societies nowadays, this kind of teacher training must be continuous, since college teaching degrees are no longer enough to support a lifetime teacher knowledge. It is expected that this research may generate new investigations and papers in this field as well as the course experienced and described in this study might become an inspiration for other teachers’ training aiming at the TPACK development.

Conflict of Interest: Authors state no conflict of interest.

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