

Mathematics Preservice Teachers' Perceptions Regarding ICT Use in Teaching and Learning Practices

Rafael Winícius da Silva Bueno ^a
Ana Henriques ^b
Lorita Aparecida Veloso Galle ^c

^a Instituto Federal Farroupilha, Mestrado Profissional em Educação Profissional e Tecnológica, Alegrete, RS, Brasil

^b Universidade de Lisboa, Instituto de Educação, Lisboa, Portugal

^c Faculdades Integradas de Taquara, Taquara, RS, Brasil

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ABSTRACT

Background: Since we have been living in the digital age, the ways of interacting with information, data and other human beings have changed. Being so, teachers need to understand their new role in pedagogical environments, changing their perspectives, and, most of all, transforming their knowledge to be able to teach with digital Information and Communication Technologies (ICT). Concerns about this new kind of teacher knowledge led to discussions that culminated, in the beginning of the 21st century, with the development of the Technological Pedagogical Content Knowledge (TPACK) framework. **Objectives:** Knowing the importance of preparing teachers to work with ICT to enrich their pedagogical practices, we propose this qualitative study that aims to analyse perceptions of a group of preservice teachers about the use of ICT in mathematics teaching and learning practices. **Design:** This study has a qualitative approach, and it can be understood as a case study. **Setting and Participants:** The participants are 10 preservice teachers from a Portuguese University. **Data collection and analysis:** Data were collected using a survey and the responses were analysed through Discursive Textual Analysis. **Results:** We understand that most participants have a well-developed TPACK and they can see several educational benefits from using ICT to teach and learn mathematics. **Conclusions:** The results of this study highlight the valuable activity of this preservice teachers' course, which is committed with the goal of helping them to develop their own TPACK.

Keywords: preservice teachers' training; mathematics education; TPACK.

Corresponding author: Rafael Winícius da Silva Bueno. Email: rafael.bueno@ifarroupilha.edu.br

Percepções de Futuros Professores de Matemática Sobre o Uso de TIC em Práticas de Ensino e de Aprendizagem

RESUMO

Contexto: Como vivemos em uma era digital, as formas de interagir com informações, dados e outros seres humanos mudaram. Os professores precisam entender seu novo papel nos ambientes pedagógicos, mudando suas perspectivas e, acima de tudo, transformando seus conhecimentos para serem capazes de ensinar com o auxílio de Tecnologias de Informação e Comunicação (TIC). Preocupações sobre esse novo tipo de conhecimento levaram a discussões que culminaram, no início do século XXI, com o desenvolvimento do Conhecimento Tecnológico e Pedagógico do Conteúdo (TAPCK). **Objetivos:** Entendendo a importância de preparar professores para trabalhar com as TIC para enriquecer suas práticas pedagógicas, propõe-se esse estudo qualitativo que busca analisar as percepções de um grupo de futuros professores sobre o uso de TIC práticas de ensino e de aprendizagem de Matemática. **Design:** Esta pesquisa tem uma abordagem qualitativa e, mais especificamente, é caracterizada como um estudo de caso. **Ambiente e participantes:** O grupo de participantes é constituído por 10 futuros professores de Matemática, que estudam em uma universidade portuguesa. **Coleta e análise de dados:** Os dados foram coletados por meio de um questionário e as respostas são analisadas a partir da Análise Textual Discursiva. **Resultados:** Entende-se que a maior parte dos participantes tem um TPACK bem desenvolvido e consegue perceber diversos benefícios educacionais advindos do uso de TIC para ensinar e aprender Matemática. **Conclusões:** Os resultados ressaltam a validade das atividades realizadas ao longo do curso no qual os participantes estão engajados, que está comprometido com o objetivo de ajudar os professores em formação inicial a desenvolver o seu TPACK.

Palavras-chave: formação inicial de professores; educação matemática; TPACK.

INTRODUCTION

Since we have been living in the digital age (Niess, 2019), the ways of interacting with information, data and other human beings have changed. These changes, regardless of what someone may think, do not make teaching an old-fashioned profession. Immersed in this ocean of information accessed every day, students need help to try to put in order this huge amount of data to try to find ways to use it to develop knowledge and autonomous thinking (Bueno & Galle, 2022).

What is different now is how teachers must do their job to really connect their classes with this new reality. According to Harari (2018), the last thing teachers should give to their students is information, because students

already have enough information online and, as he points out, maybe they even have too much of it to process. Within this context, teachers need to understand their new role in pedagogical environments, changing their perspectives, their epistemological views and, most of all, transforming their knowledge to be able to teach with digital Information and Communication Technologies (ICT).

With this new kind of knowledge, teachers should be able to “transform the content, as they know it, into content meaningful for their students while using technological learning tools” (Niess & Gillow-Wiles, 2017, p. 79). But this goes beyond the simple use of technological resources to replicate the same traditional practices. This involves different forms of interaction with students, different ways to represent and present ideas and concepts, and a whole different kind of pedagogical plans that teachers need to build up from new knowledge regarding technology, pedagogy and subject matter.

Concerns about this new kind of teacher knowledge and regarding how to prepare teachers for ICT integration into their classes led to discussions that culminated, in the beginning of the 21st century, with the development of the Technological Pedagogical Content Knowledge (TPACK) framework. This construct began with Niess (2005) working with Mathematics Education and was extended to other teaching and learning areas by Mishra and Koehler (2006).

Knowing the importance of preparing teachers to work with ICT to enrich their pedagogical practices, we propose this qualitative study that aims to analyse perceptions of a group of preservice teachers about the use of ICT in mathematics teaching and learning practices. These preservice teachers were engaged, at the time we conducted this research, in a Didactic of Mathematics course from Teaching Mathematics master program of a Portuguese University. To perform this study, we sent them a questionnaire and their responses were analysed through the lens of the TPACK framework.

THEORETICAL BACKGROUND

Concerns about teachers' knowledge are not new. We can trace it back, for example, to the 1980s, when Shulman (1986) proposed the construction of the Pedagogical Content Knowledge (PCK). It was described by this author as a special kind of knowledge that involves comprehension about the most powerful ways of representing and explaining scientific knowledge in order to make it more accessible to students. This comprehension involves teachers' understanding of what can make the learning process easier or more

complicated and teachers' perception of the students' preconceptions that can be used by these students when new ideas are explored in class.

With PCK, Shulman (1986) argues that Content Knowledge and Pedagogical Knowledge should not be seen as two separate kinds of teachers' knowledge. In fact, he highlights the importance of building an intersection among these two domains and of using this intersection to guide teachers' practices. According to Ball et al. (2008, p. 389), "the continuing appeal of the notion of pedagogical content knowledge is that it bridges content knowledge and the practice of teaching".

PCK was crucial then to build a resignification of teachers' knowledge necessary to teach. Shulman's (1986) ideas were revolutionary, once the research on teacher education, until that time, focused on more general aspects of teaching practices. Like Angeli and Valanides (2009, p. 155) affirmed, PCK is related to "a transformation of subject matter knowledge so that it can be effectively and flexibly used in the communication exchange between teachers and learners".

In a similar way as happened with PCK in the 1980s, in the beginning of the 21st century, emerged a concern regarding the integration of technological knowledge into teachers' education and professional practices. In this context, resulting from the work of multiple scholars, was proposed the Technological Pedagogical Content Knowledge (TPACK) framework (Koehler & Mishra, 2005; Niess, 2005; Pierson, 2001; Zhao, 2003).

Technological Pedagogical Content Knowledge

With the challenge of understanding how to prepare teachers to use ICT as a new component of teaching and learning dynamics and to help them to "develop an overarching conception of their subject matter with respect to technology and what it means to teach with technology" (Niess, 2005, p. 510), emerged, in the beginning of the 21st century, the TPACK framework. As argued by Mishra and Koehler (2006), the TPACK framework aims to emphasize connections, interactions and possible limitations existing among technological, pedagogical and content knowledge. According to Niess (2015), TPACK can be described as a dynamic construct that teachers rely on when they plan and conduct classes in which students learn using ICT.

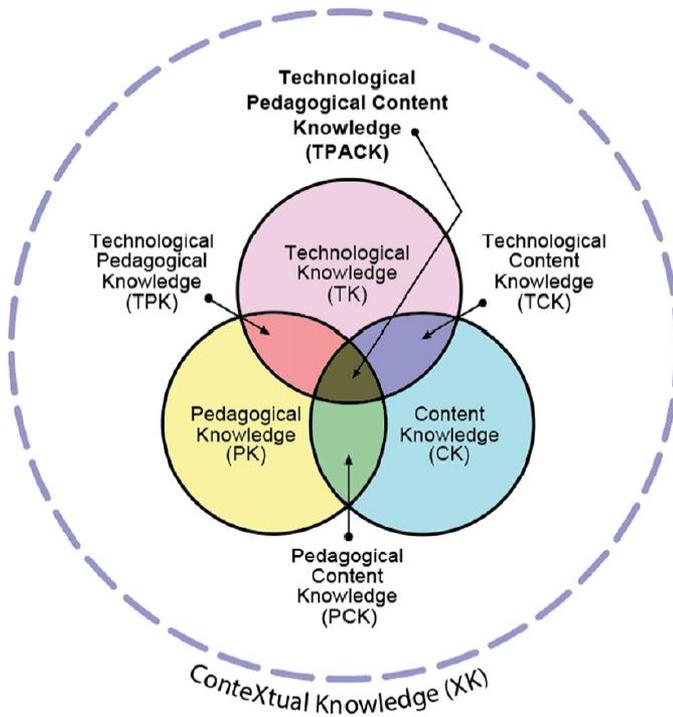
To develop TPACK, teachers need to understand how to conciliate knowledge about technology, pedagogy and content. This is not an easy task,

once one cannot simply add technological knowledge (TK) to the PCK amalgam of content and pedagogical knowledge (Angeli & Valanides, 2009). Being so, TPACK must be seen as a new kind of fluid, homogenous and transformative knowledge that keeps evolving while ICT and students continuously change. To reach this goal, as Cejas-Léon and Navío-Gómez (2020) argue, it is necessary to take teachers beyond the mere comprehension of how to work with some specific ICT tools to help them to visualize how to connect digital resources with their teaching practices to really improve it.

To visually translate these ideas, Mishra (2019) proposed the diagram shown in Figure 1. It describes the interactions among technological, pedagogical and content knowledge and recognizes the importance of the context of the teaching and learning practices by highlighting the ConteXtual Knowledge (XK).

Figure 1

Visual description of TPACK. (Mishra, 2019, p. 77)



Cibotto and Oliveira (2017) argue that the perception about the context that influences teaching and learning practices is a fundamental part of TPACK. In this sense, Mishra (2019) states that XK includes teachers' perceptions about the ICT available at the school and the knowledge regarding (social, cultural, economic, etc.) characteristics of the neighbourhood, city and state where this school is located.

According to Lyublinskaya and Kaplon-Schilis (2022, p. 2), “the central TPACK domain is then considered as an integrated knowledge, a distinct form of knowledge where the inputs have been integrated in such a way that none are individually discernible”. Sharing this comprehension about TPACK, Niess (2015, p. 21) highlights that “the centre intersection called TPACK is the desirable teacher knowledge that teachers rely on, when designing and implementing curriculum and instruction, while guiding students’ thinking and learning with digital technologies”.

From these ideas regarding TPACK, we can conclude that just knowing how to use some ICT resource does not guarantee its effective integration in pedagogical practices (Dalal et al., 2021). To enhance teacher practices with ICT, it is necessary that the 21st century teachers develop a homogenous mixture of knowledge regarding technology, pedagogy and content, always considering the context where the teaching and learning dynamics occurs.

Mishra (2019) affirms that TPACK framework has been widely used as reference in research, pedagogical practices and to develop and enhance teachers’ education courses. Discussing teacher training, Janssen and Lazonder (2016, p. 121) argued that “teachers who are inexperienced in the integration of new technologies in their classes need support. This support should be aligned with teachers’ current TPACK level”. The level mentioned in this sentence is a reference to the work of Niess and her colleagues (Niess, 2013; Niess et al., 2009) regarding mathematics teachers’ TPACK development.

Mathematics Teachers’ TPACK Development

Performing research-based observations of mathematics teachers using spreadsheets as technological tools to teach and learn mathematics, Niess’ research group (Niess, 2013; Niess et al., 2009) created a five-levels model of TPACK development to describe teachers’ acceptance or rejection of ICT as subject matter learning tools. According to Niess and Gillow-Wiles (2017) these levels can be described as it follows:

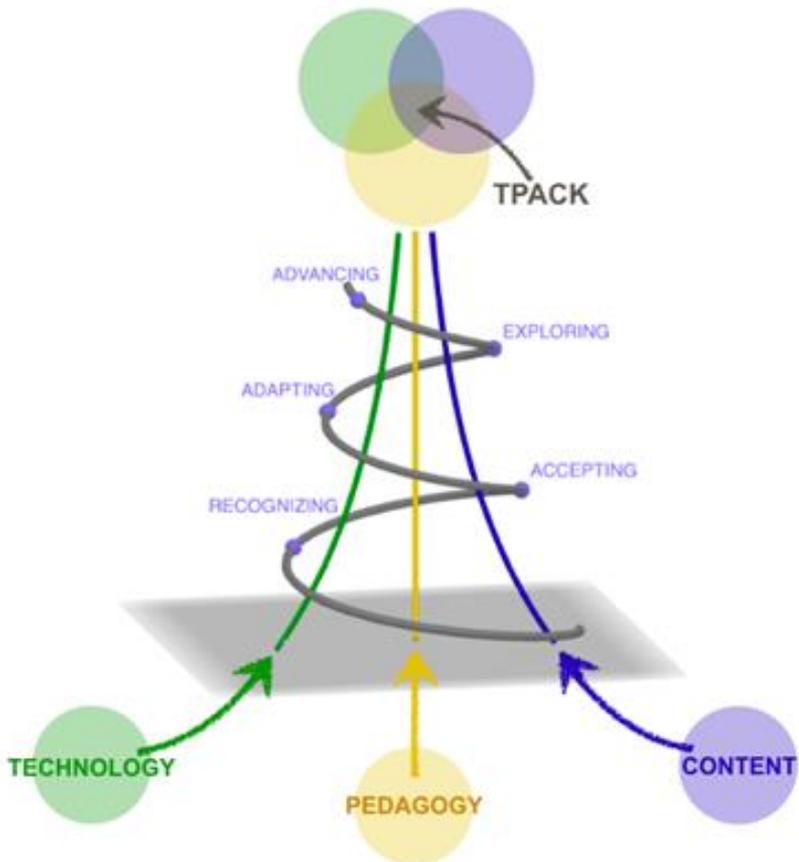
1. *Recognizing* - when teachers are able to use technologies and recognize the alignment of the technologies with the mathematical subject, but they are not yet integrating ICT in their pedagogical practices. It happens because these teachers are often concerned about the time spent to help students to understand how to use ICT. These teachers use technologies only to revisit some ideas and concepts previously discussed in classes.
2. *Accepting* - when teachers form a favourable (or unfavourable) attitude toward teaching and learning mathematical content with appropriate ICT tools. These teachers use technologies at the end of the classes or units of instruction, in complementary activities or in classes in which new mathematical topics are not discussed. Since these teachers are still insecure regarding the ICT use to teach and learn, they try to closely control the ICT use by the students.
3. *Adapting* - when teachers engage in activities that lead to a choice to adopt (or reject) teaching and learning specific content topics with appropriate technologies. Once they choose to adopt ICT in their teaching practices, it is used to reinforce or better explain mathematical concepts or ideas that have been previously taught without ICT use. Simple practices with ICT start being used in class adapting these practices to the class context. Pedagogical approaches are mostly teacher centred, once these teachers are still concerned about holding control of their class progress.
4. *Exploring* - where teachers actively integrate teaching and learning of mathematical content topics with appropriate technologies. These teachers start involving their students into more and more sophisticated dynamics permeated by ICT tools, such as mathematical modelling or problem solving. Teachers in this level play a different role in class, as they become to be mediators of the teaching and learning interactions and tending to use different teaching approaches catalysed by different kinds of technological resources.
5. *Advancing* - when teachers evaluate the results of the decision of integrating appropriate ICT in teaching and learning mathematics and are willing to make changes in the curriculum to take advantage of the affordances of these technological resources. At this level, teachers begin to adapt different teaching approaches using ICT to help students to better understand mathematical contents. These teachers use different teaching practices with a considerable presence of ICT, aiming to keep students engaged in

classroom activities and to enhance their autonomy to develop mathematical knowledge.

Niess et al. (2009) argued that TPACK is gradually developed through these five levels and that this development does not occur in a regular way or through a consistent growing pattern. Being so, Bueno et al. (2021) proposed, as can be seen in Figure 2, a diagram to illustrate the smooth and continuous developing of TPACK.

Figure 2

Visual description of TPACK development. (Bueno et al., 2021, p. 113)



This illustration shows a converging 3D spiral that aims to highlight how technology, pedagogy and content come closer as the development path passes through different levels of TPACK. The spiral movement suggests the idea of passing through proximal zones as one travels through this pathway. This diagram still allows adjustments of the distances between each two levels. This means that the levels do not necessarily have to be equally distant from each other, which reveals that there is different (personal) timing for each teacher to evolve from one level to the next one (Bueno et al., 2021).

Aiming to investigate the evolution of TPACK through these five levels, Niess et al. (2009) highlighted four aspects of teaching practice: *Curriculum and Evaluation*; *Learning*; *Teaching*; and *Access*. Once the participants of the present study are preservice teachers (in Portugal one can teach only after finishing a teaching masters course) we decided to limit our discussion to *Teaching* and *Access* aspects. This choice is due to the fact that preservice teachers, according to Bueno et al. (2021, p. 114), are still “not acquainted with specific practical elements of classroom interaction with ICT”.

As Niess et al. (2009) affirm, *Teaching* dimension of TPACK development is linked to methodological approaches, teaching environment management and professional teaching development. On the other hand, *Access* aspect is related to the possibilities of ICT use by the students, possible existing barriers that might be prejudicial to ICT integration in teaching and learning environments (and how teachers address to these barriers) and how new technologies can make sophisticated mathematical ideas more accessible to a greater and more diverse number of students.

METHODOLOGY

The present study has a qualitative and interpretive approach. According to Bogdan and Biklen (2013) this kind of research valorises interpretation, description, well-grounded theory and researchers’ personal perceptions. To be more specific, this work can be understood as a case study (Yin, 2001), which uses a particular scenario to develop ideas that can be extended to different contexts (Ponte, 2006).

The participants of this study were 10 preservice teachers engaged in a Didactics of Mathematics course from a Teaching Mathematics master program of a Portuguese University. The Didactics of Mathematics course has as its goals: (a) to help future mathematics teachers to develop knowledge and didactical resources to teach mathematics, and (b) to provide a space for them

to discuss and think about transversal approaches to teach mathematics. To do so, according to the course teaching plan, theoretical and practical activities are conducted in its weekly classes, during the whole semester.

To collect the data analysed in the present research, we propose to these preservice teachers an online survey. According to Laville and Dionne (1999), this kind of research instrument is formed by a range of questions created by the researchers to help them to reach their research goals. Being so, the survey we created had multiple-choice and open-ended questions. In the case of the open-ended questions, participants have an opportunity to better express their individual thoughts about the explored subject.

The online survey¹ we sent to the participants had 14 questions: 13 multiple-choice questions and one open-ended question. The first two questions aimed to collect data to help us to characterize the participants regarding their age and nationality. The following 11 questions aimed to collect data related to their relation with ICT. The last question, the open-ended question, was built to help us to better understand participants' perceptions about the use of ICT resources to teach and learn mathematics.

From the two first questions, we discovered that participants' ages were between 23 and 51 years old and that six of them are from Portugal, two from Brazil, and two from Guinea Bissau. From the next 11 questions, we collect data related specifically to ICT. In this sense, questions three to eight were related to their formation on the use of ICT tools and to the intensity of using these tools during their master course until then.

Regarding their formation on the use of ICT tools (question three), most participants affirmed that they learned how to use ICT in part on their own and in part on their graduation course. When asked about the use of emails to interact with their classmates or with their master course teachers (question four), half of the participants answered that they use it always, while half of them answered that they use it almost all the time. Regarding the use of forums

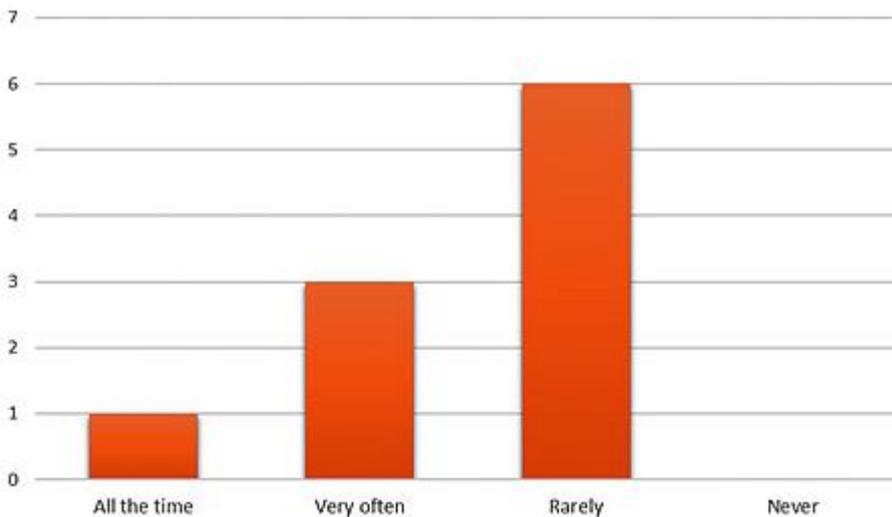
¹ The ethical questions necessary for this investigation were ensured using fictitious names to guarantee the total anonymity and confidentiality of the participants who voluntarily agreed to participate in this study. Besides that, an informed consent was signed by all the participants. This is the normal procedure in Portugal to this kind of research. We also would like clear that *Acta Scientiae* has no responsibility in any possible consequence of this study, including assistance and possible compensation for any resulting damage to any of the research participants, in accordance with resolution n° 510, of April 7, 2016, of the National Health Council of Brazil.

to discuss ideas studied on their master course (question five), half of the preservice teachers responded that they rarely use this kind of tool, two said that they never used it, two answered that they use it very often and one said that he/she always uses it.

When the subject of the survey turned to the use of word processors, spreadsheets or presentation software (question six), six preservice teachers said that they use it very often, while four affirmed to use it all the time. Faced with the question that dealt with the use of software more frequently used to teach and learn mathematics (question seven), such as GeoGebra and TinkerPlots, most participants, as can be seen in Figure 3, said that they rarely use these kinds of ICT tools. Moreover, when the preservice teachers were asked about the frequency of the internet use to search for relevant information to their professional development (question eight), most of them claimed that they use it all the time, while two affirmed to rarely use it, one said that he/she never uses it and one claimed that he/she uses it very often.

Figure 3

Participants' frequency of use of software related to Mathematics teaching and learning.



Continuing the survey, questions nine to 13 were built to search for evidences more directly related to the five levels of TPACK development. We aimed to do this by relating the questions with the future teaching practice of the participants regarding the use of ICT resources to teach and learn mathematics.

Being so, when asked about how frequently they intended to use ICT tools in their future classes (question nine), half of them said that they intend to use it often, while three affirmed to have the idea of using it sporadically and two said that they intend to use it always. Regarding how they think they will feel about using ICT tools in their future teaching practices (question 10), most participants (six) affirmed that they will enjoy using it, three think that they will use ICT resources but still with some limitations of use, and one said not feeling comfortable enough to use it in his/her class.

In question 11, we sought information regarding how these preservice teachers feel about their ICT skills. In this specific question, participants could check more than one option of answer (checkbox question). We discovered that nine of them claimed to have knowledge to select and use ICT to improve teaching approaches and students' learning processes. Still in the same question, seven participants answered that they know how to build a teaching plan to promote mathematics learning with the use of ICT tools, and seven claimed to know how to use ICT to better evaluate students' learning during classes. These answers indicate, according to Niess et al. (2009), higher levels of TPACK development.

In question 12, we asked the participants to select one of the possible choices we gave them to complete the following sentence: *when you think about teaching and learning mathematics with the use of ICT resources, you...* Within this context, that is related to the mathematical learning descriptor of the *Teaching* dimension of TPACK development model, answers were more divided. Three preservice teachers said that they try to understand ICT resources as significant tools to teach and to help students to learn mathematical concepts and ideas. This thought can be related to the higher level of TPACK development model: *Advancing*. Moreover, two participants answered that they think that ICT use can help to engage students in more sophisticated thinking activities. This affirmative is related to the *Exploring* level of TPACK development. Still in this question, two participants said that they think that ICT tools can be used to enhance or reinforce mathematical ideas previously studied in class. This answer is linked to the *Adapting* level of TPACK development.

Besides these answers related to higher levels of TPACK development, we had two preservice teachers saying that they think that ICT tools are more adequately to be used at the end of subject matters units or on “days off”, which can be connected to the *Accepting* level of TPACK development. Finally, one participant affirmed to worry about the time spent to teach students how to use technology. This answer is related to the *Recognizing* level of TPACK development.

The 13th question was a checkbox question regarding how these preservice teachers think they probably will use ICT tools in their future teaching practices. The possible answers were related to the environment descriptor of the *Teaching* dimension of the TPACK development model (Niess et al., 2009). The most checked answers were from two distant levels of TPACK development. Seven participants said they will probably use ICT resources only to revisit ideas previously studied without any help of technologies (*Recognizing*) and seven affirmed they will probably behave more as learning guides, proposing technology-enhanced activities and students’ centred approaches in their classes (*Advancing*).

Still in this question, six preservice teachers answered they will probably adapt a range of teaching approaches using ICT tools to help to engage students in thinking about mathematics. This answer is related to the *Exploring* level of TPACK development model. The same number of participants said that they think they will adapt a few instructional approaches to use ICT resources to help students to explore part of their lessons with technologies. This idea can be traced back to the *Adapting* level of TPACK development.

At this point, we reach the last question (14th) of the survey: *how do you feel about the use of ICT resources to teach and learn mathematics?* The answers given to this question are the core of the corpus analysed in our study through the Discursive Textual Analysis (Moraes & Galiuzzi, 2016). This kind of methodological approach aims to analyse qualitative data and information to develop new understandings about the studied phenomena.

According to Galiuzzi and Sousa (2022), the Discursive Textual Analysis is a process composed of three moments: unitarization, categorization and metatexts creation. In the first one, the texts of the corpus are divided into smaller fragments, named sense units. With the sense units built, researchers start working on the categorization by creating or establishing possible connections between these units to create emergent categories to be discussed. The categorization, as Moraes and Galiuzzi (2016) argue, is a process of creation, ordering, organization and synthesis.

The final moment of Discursive Textual Analysis consists in the communication of the new emergent ideas. Being so, descriptive and interpretive metatexts are built using fragments of the participants' narratives (sense units), researchers' personal interpretations, and ideas from the theoretical scope used in the research.

RESULTS AND ANALYSES

As explained in the previous section, Discursive Textual Analysis culminates with the communication of new emergent ideas through the metatexts. In the present research, we created two emergent categories to be discussed: *Benefits* and *Concerns*. The metatexts corresponding to each one of these emergent categories are presented below. To preserve participants' identities, they are identified in the metatexts as P1, P2, P3, ..., P10.

Benefits

From the 31 sense units identified on the preservice responses, 20 originated the present emergent category. In spite of all of these 20 sense units being linked to possible benefits resulting from ICT use to teach and learn mathematics, we were able to identify benefits that can be related to different TPACK development levels.

Within this context, P6 stated that a relevant benefit of ICT use in pedagogical practices is "the simplification of teachers' work". It looks like ICT resources are understood here just as new tools to help teachers keep doing the same old things. Instead of writing the same definitions, theorems and formulas in every single class, now teachers can write it just one time on a PowerPoint slide and show it repeatedly every semester or every year. Instead of drawing the same pyramids, cubs or spheres in every single geometry class, now teachers can do it just one time using GeoGebra and show the same file or applet repeatedly during their classes. These kinds of thoughts show an isolated technological knowledge, because we cannot see here any relation created among technology, pedagogy and content to enrich and improve students' learning in pedagogical practices.

In other responses, we can see discourses more concerned with students' learning, even though some of these responses are still related to initial levels of TPACK development. For instance, P3 said that technological resources can be "important to help teachers to represent and explore greater numbers of

figures and functions in a more accurate way”. With a similar idea, P1 argued that “the main benefit of using ICT is related to the visualization” of different mathematical objects. We can interpret these thoughts as being based on pedagogical practices centred on teachers' actions, who use ICT tools mainly to show different representations to their students. In this same line of thought, P3 said that ICT brings into class “a greater power to calculate”.

We understand that these last three participants' quotations show a fragmented teacher knowledge, being all related to what Mishra and Koehler (2006) called Technological Content Knowledge (TCK), which is the intersection between technological and content knowledge, but still without a meaningful integration of pedagogical knowledge into this mixture. Looking at the TPACK development model, we can find characteristics of the *Accepting* level on these sense units. At this level, teacher use, for instance, dynamic geometry software to enrich students' visualization, but he/she “tightly manages and orchestrates instruction using technology” (Niess et al., 2009, p. 22).

Moving forward on the TPACK development model, we found some participants' ideas related to more advanced levels. In this sense, P8 affirmed: “ICT help students to learn, because it enables them to redirect their attention from doing mathematics to thinking about mathematics”. In this scenario, teachers work at the *Exploring* level, because they try to engage students in “thinking activities for learning mathematics using the technology as a learning tool” (Niess et al., 2009, p. 23). As stated by P9, this kind of teaching practices can “contribute a lot to improve teaching and learning quality”.

At the *Exploring* level, teachers leave the central role in the classroom and start working more as learning guides. Being so, students are encouraged to “explore and consolidate mathematical ideas and concepts” (P7) in a more autonomous way, which can be, according to P2, more “stimulating to learn mathematics”. Being more free to use ICT tools by themselves, students “can develop different and personal comprehensions regarding some specific subject matter” (P8). Interpreting these sense units, we can understand that these preservice teachers have “a clear vision of the pedagogical relevance of ICT” in digital age classes (Tondeur et al., 2012, p. 4).

Concerns

Participants' responses originated 11 sense units that can be understood as concerns regarding the use of ICT tools in mathematics classes. It is the case of P6, who suggests that ICT can cause “students dispersion of interest leading

to a non-favourable environment to learn”, and of P4, who argues that ICT use “may lead to distractions”. Dealing with the *Access* aspects of TPACK, this kind of concern can be related to the *Accepting* level of TPACK development. At this level, teachers still worry “about access and management issues with respect to incorporating technology in the classroom” (Niess et al., 2009, p. 24). Teachers at the *Accepting* level still prefer to let students use ICT tools only in some isolated classes or in not so important learning situations. Being so, teachers understand that they can keep everything under their control and can avoid the lack of interest that they think ICT can bring to class.

It looks like these preservice teachers are concerned with the possibility that their future students can use digital resources to “escape” from their classes, surfing on the web or maybe playing some online game. At this point of classes teachers’ work should come forward, providing students with pedagogical dynamics in which, as suggests Dewey (1979), students’ natural curiosity can be redirected to learning activities. In the digital age, it can be done with the use of TPACK to engage students in activities with a “high level of cognitive demand throughout lessons” (Lyublinskaya & Kaplon-Schilis, 2022, p. 4).

Looking to *Teaching* aspects of TPACK, participants' concerns can be traced back to the initial level of TPACK development model: *Recognizing*. Within this context, participants mentioned, very often, concerns regarding the time they might need to spend to teach students how to use digital ICT, because of students’ lack of digital skills. It is the case of P1, when he/she says that “ICT use can be an obstacle, because students need to learn how to manipulate digital resources with some fluency, which can take too much time”. With the same line of thought, P8 argues that ICT use “can become a problem in cases in which students are not so familiar with some software”.

It looks like these preservice teachers do not understand that students can learn mathematics while they learn how to use some specific digital tool. One does not need to know everything about the use of GeoGebra, for instance, to use it to learn about triangles or rectangles. In fact, at the same time as students learn about a specific GeoGebra button or tool they can also learn about Geometrics or Algebra. In this kind of occasion, TPACK helps teachers to use something that initially could be seen as a problem to enhance learning situations (Ali et al., 2020).

These concerns show that these preservice teachers still think that, while students are learning how to use some digital tool, they cannot use it to “develop mathematical concepts” (Niess et al., 2009, p. 22). This may be one of the reasons why “many teachers struggle with using technology in their

classrooms, whether in physical or virtual environments” (Lyublinskaya & Kaplon-Schilis, 2022, p. 1).

With a well-developed TPACK, teachers can (and should) adapt their class plans according to the class of students in which they are working. This kind of plan movement can be related to teachers’ comprehension regarding the differences of students’ ICT knowledge or skills existing from one school or class to another. This comprehension comes with the development of XK that, as Mishra (2019) points out, involves from teacher awareness of available ICT tools at school to teacher knowledge of students’ access to technology.

The first step moving forward XK is related to teachers’ understandings that there are contextual differences to be considered. It is the case of P6 who claim that “there are some setbacks that might be presented, such as schools lack of resources to help teachers to promote learning with ICT”. Koh et al. (2014) pointed out in their research that problems with access to digital ICT tools and proper functioning of computers and software are critical factors that affect teachers’ willingness to incorporate technology into their classes.

In the case of lack of technological support from the school, for whatever the reason it might happen, teachers can suggest students to use, for example, their smartphones. There are a lot of digital resources available for this kind of artefact, such as GeoGebra, Kahoot and Mentimeter. Of course, this is not the ideal scenario, but can be helpful while school looks for more definitive solutions.

Koh et al. (2014, p. 21) highlight that TPACK has “a transformative nature where teachers’ interpretation of contextual demands can shape how they draw upon and integrate their different knowledge sources”. So, one of the key factors to adapt class plans to different pedagogical contexts is the development of TPACK as a transformative knowledge, as an amalgamation, as a homogeneous mixture. With this kind of TPACK development, teachers can create better alternatives to deal with continuous change of schools, students and technologies.

CONCLUSIONS

This case study was carried out in a preservice teachers’ learning scenario of a Didactics of Mathematics course that aims to better prepare preservice teachers to work with ICT. In spite of teaching mathematics with the help of ICT still being an innovative practice in Portugal, we understand that it

is necessary to help preservice teachers develop their own TPACK so they will be able to enrich their future pedagogical practices. The collected data from the proposed questionnaire provided an opportunity to analyse the preservice teachers' perceptions about the ICT use in mathematics teaching and learning practices. From the Discursive Textual Analysis, we were able to build two emergent categories: *Benefits* and *Concerns*.

On the *Benefits* emergent category, preservice teachers pointed out that ICT can help them to enhance their pedagogical practices. In spite of the general idea of understanding ICT as something good to teaching and learning environments, participants referred to it in different ways that were related to different levels of TPACK development. While some of them described benefits only related to their teaching work, others mentioned benefits linked to the improvement of students' learning and mathematical thinking. Being so, we can conclude that these preservice teachers are going forward to reach and improve their own TPACK. Some of them just have longer paths ahead before getting there, once their ideas can still be related to more initial levels of TPACK development.

On the other hand, the *Concerns* emergent category brings participants' ideas that show they still have some concerns regarding using ICT in mathematics teaching and learning environments. Some preservice teachers argued that it might require too much class time to help students to get some digital fluency so they can finally be able to use digital resources to learn. Other participants think students can simply forget about the class to go surf on the internet waves to find something more attractive to do. But there are participants related to this category that apparently do not think of using ICT to teach only because they think schools do not have enough support or technological resources to make it possible.

In spite of some concerns expressed in the second emergent category, we understand that the results of the study showed positive development of participants' TPACK from their experiences in working with ICT, and from the opportunity they had of exploring different technologies, what led them being able to identify the ICT potential and to recognize how the increasing integration of technology in pedagogical practices can be favourable to teach and learn of mathematics. We noticed, as well, that most of the time they made explicit their intention to adapt and improve a range of teaching approaches using ICT resources to better explore mathematical concepts and ideas through different representations. This line of thought shows that these preservice

teachers are thinking of using ICT to improve learning experiences and not just to help them to make their job easier.

We can thus conclude that the results of this study highlight the valuable activity of this preservice teachers' course, which is committed with the goal of helping preservice teachers to develop their own TPACK. It is one of the several initiatives we have been developing in Portugal to move forward on effectively integrating technology in mathematics teaching and learning practices.

One recognized limitation of this study is the fact that it was not possible to give participants the opportunity to carry out a real class experiment using technology, with real students, to then analyse the experience and reflect on its implementation. It was not possible, because this course happens in the first year of the master program. So, we hope we can provide more thoughts when, in the second year of this program, an experience will be carried out as it is important that preservice teachers “have more opportunities to get in touch with concrete experiences of using technology with students and, hopefully, to put their plans into practice, reflecting on their implementation in the classroom” (Oliveira et al., 2018, p. 441). With the new data, we expect to be able to relate these initial thoughts about ICT integration into class experiences with the real practice to then verify if there are semblances and try to understand how this transition occurs.

AUTHORS' CONTRIBUTIONS STATEMENTS

R.W.S.B., A.H. and L.A.V.G. conceived the presented idea. Both developed the theoretical study and adapted the methodology to this context. They also collected and analysed the data together. All authors actively participated in the discussion of the results, reviewed and approved the final version of the work.

DATA AVAILABILITY STATEMENT

The data supporting the results of this research can be made available by the corresponding author (R.W.S.B.), upon reasonable request.

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