The use of the TPACK framework on research about teachers' knowledge to teach with digital technology

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The potential of digital technologies for teaching and learning mathematics is widely recognized and teachers' knowledge is one of the elements impacting their integration. Several authors have intended to characterize the teachers' knowledge required and developed several models, being TPACK one of these models. In this study, we seek to conduct a systematic review of the research on the integration of digital technologies by mathematics teachers based on the TPACK model. Specifically, we intend to answer the following research questions: (1) What are the main methodological options adopted? (2) How is the framework operationalized/used in the studies? The review was based on a search in the Scopus database and resulted in the identification of 10 relevant documents. The analysis suggests a prevalence of qualitative approaches, but a strong use of questionnaires; and an integration of the model with other frameworks, namely the developmental model of TPACK.

Keywords: Teachers' knowledge, TPACK, systematic review.

The research on teachers' knowledge

Digital technologies have long been recognized by their potential to promote mathematical learning (Tabach & Trgalová, 2019). However, achieving that potential has proved to be quite a challenge, with several authors recognizing the central role played by the teachers (Clark-Wilson et al., 2020).

Technology integration into teachers' practice is a complex process, affected by several elements, and one of these is the teachers' knowledge (Rocha, 2020). Characterizing teachers' knowledge and understand how to promote its development has been the focus of many studies and of many projects and similar initiatives, as discussed by Faggiano et al. (2021). However, this has not been an easy task. Several questions were raised. There was a need to understand what a teacher needs to know to be able to use the potential of technology to promote students learning. This includes understanding the teachers' knowledge, but also understand how to promote its development. As discussed by the authors, the first attempts to promote the development of teachers' knowledge were based on technical knowledge of the technology (i.e., knowing how to operate the technology) and failed. This analysis led to the need of considering more than just offering teachers access to technology and some technical support.

Even before digital technology, several authors have intended to characterize the teachers' knowledge and developed several models. Starting from the inspiring work of Shulman (1987) and his PCK – Pedagogical Content Knowledge construct, and going thought all the authors who used it and developed clarifications and extensions (Sevinc, 2023), until the very well-known refinement of the PCK proposed by Ball et al. (2008), we have come a long way that helps us to better understand what teachers need to know to teach.

As discussed before, the integration of technology into teachers practice has raised new challenges. It was clear that teachers need some knowledge about technology, but very soon it was clear that

some additional knowledge would be need. Inspired by the work of Shulman and his PCK construct, some more specific models were developed. One of these models was TPACK. Developed by Misha and Koehler (2006), this is probably the most well-known model with a focus on technology integration.

The TPACK model considers the Content and Pedagogy knowledge domains, assuming PCK as the intersection between these. To these domains the authors add the one on Technology, considering then the intersections among all the domains: Content and Technology, Pedagogy and Technology, and the intersection among all the domains – the TPACK. The Context is also considered, although in different ways over time, only recently being assumed as a knowledge domain (Mishra, 2019).

However, the research based on knowledge models has been criticized because of the way it uses these models, often with a greater focus on distinguishing between different domains of knowledge than on their operationalization (Ruthven, 2011). Another point, addressed by Tabach and Trgalová (2019), has to do with the focus of the study. According to the authors, most of the studies are content-driven or tool-driven. Those who are content-driven focus on the knowledge and skills needed to teach a specific content using technology (e.g., functions). Those who are tool-driven focus on the knowledge and skills needed to use a specific technology to teach mathematics (e.g., graphing calculator). A more global view would be important to develop a deeper understanding of technology integration.

The research approach based on knowledge models has also been criticized by its focus on a static approach (Tabach, 2011), not valuing the dynamic character of the teachers' professional development and, specifically, of their knowledge. Some of the studies tend to address the teachers' knowledge disconnected from their practice, without taking into account the difference that may exist between a task (what it presupposes) and its implementation (Rocha, 2022).

These critics have been considered and resulted in proposals of refinements, new models of teachers' knowledge, or the use of the knowledge models combined with other frameworks to somehow overcome the weakness identified in the model. However, this development of the field calls to deeper analysis and reflection.

Goals and research questions

As a knowledge model, the TPACK model has been the target of several criticisms, as referred before. However, the model continues to be used by many authors in their studies. As so, it will be important to understand how the model is being used in the field of mathematics education.

In the study presented here, we seek for an overview about how the TPACK framework is being used in research about digital technology. As so, our focus is on the methodological options and on the use of the model. Specifically, we intend to answer the following research questions: (1) What are the main methodological options adopted? (2) How is the framework operationalized/used in the studies?

Methods

This work is part of an ongoing study with focus on teachers' knowledge and the different frameworks about it. In this part of the study, we focus on the TPACK model. The work presented here was developed according to the guidelines provided by PRISMA (Page et al., 2021). We assume Scopus as the database for our search, due to its international recognition and representativity. The search for

documents was planned for a period of ten years (2014-2023), and done in the title, abstract and paper keywords. We started using the keywords: technology, TPACK. This resulted in 1592 papers. Due to our focus, we added another keyword: teachers' knowledge. This resulted in 187 documents. However, several of them are not related to mathematics, as so we added mathematics to our keywords. As a result, we got 34 papers. We then limited our papers to those published in journals and written in English. The result was 19 papers. Finally, we added the time frame, resulting in 12 papers. Having 12 papers published in the last ten years, out of a total of 19 papers, suggests this is a good time frame to consider. After a full reading, two of the papers were excluded because they were more an analysis of one course than a research study using the TPACK model. This resulted in a total of 10 articles analyzed in this review (marked with * in the references).

The analysis and interpretation of the documents was then guided by a set of categories defined based in the research questions. The information from the full read of the articles was entered in a spreadsheet organized according to: the authors' name, date of publication, journal name, goal/research questions, framework used and methodological options. The focus of this review is on the methodological options. As so, attention was given to the type of methodology (qualitative, quantitative, or mixed), to the number of participants and to their type (pre-service or in-service teachers), instruments used to collect data, and to the characteristics of data analysis.

Results

From the 10 articles analyzed, in what concerns to the date of publication, two were published in 2023, two in 2022, two in 2020, two in 2019, one in 2018 and one in 2014 (not considered in this study due to the time frame defined: four in 2013, one in 2012, and two in 2010). A fact suggesting the research using the TPACK model has received attention in the last 25 years, with a very slight increase in the interest in the more recent years.
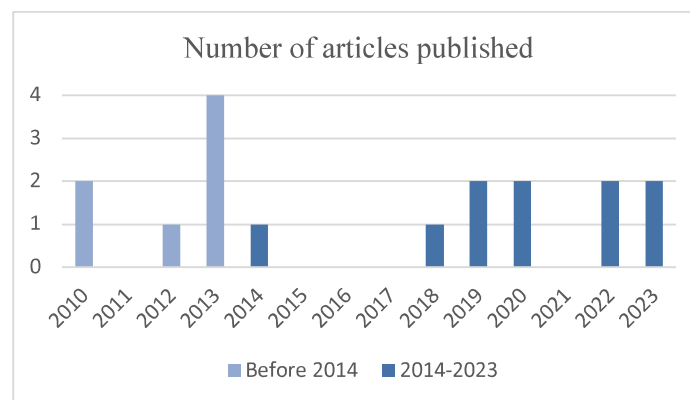

Figure 1: Number of studies with a focus on Mathematics using TPACK model

In terms of the type of methodology adopted, most of the studies adopted a qualitative methodology, three were based on questionaries and quantitative methodologies, and one adopted a mixed methodology, with a quantitative part based on a questionnaire applied to 33 pre-service teachers, and then a qualitative part, involving 6 of these participants (Table 1). In both cases, qualitative and quantitative studies, the participants are pre-service or in-service teachers, with one case of a qualitative study with teachers' educators and one case of a quantitative study with pre-service special education teachers.

Table 1: Type of methodology and type of participant in each study

	Quantitative	Mixed	Qualitative
In-service teacher	2	-	4
Pre-service teacher	1	1	2
Total	3	1	6

The number of participants in the study varies significantly, with lower numbers in qualitative studies (Table 2). Even so, some of the qualitative studies have a high number of participants, even when the methodology adopted is the case study. That is the case of one study involving 52 in-service teachers.

Table 2: Type of methodology and number of participants in each study

	Quantitative	Mixed	Qualitative
In-service teacher	86, 202	-	3, 13, 16, 52
Pre-service teacher	116	33 (quant.) – 6 (qualit.)	10, 21

For quantitative studies, the questionnaire is the instrument for data collection. For the qualitative studies the instruments are more diversified (Table 3). Although the questionnaire is also used (in one study), interviews and observations are dominant, with references also to other instruments, such as document gathering and field notes. Two of these studies are lesson studies, and two others, although not being present as lesson studies, are based on working sessions to prepare lessons and in the analysis of the teachers' lesson plans.

Table 3: Type of data collection in each study

		Quantitative	Mixed	Qualitative	Total
Questionnaire		3		1	4
Observation, interviews, document gathering	Simple			2	2
	Lesson study		1	1	2
	Working sessions, lesson plans			2	2
Total		3	1	6	10

The data analysis is based in statistics in the case of quantitative studies, in some cases using the software SPSS. In the case of qualitative studies, the analysis is often based on codification, using categories usually related to the theoretical framework.

Only one study organizes the data collection based on the knowledge domains of TPACK. Almost half of the studies (four) combine the TPACK model with the development model by Niess et al. (2009) and Niess and Gillow-Wiles (2017) and base the data analysis on the five levels of development – recognizing, accepting, adapting, exploring, and advancing. Other studies combine the TPACK model with other framework, such as the instrumental approach (two studies: one instrumental genesis and one documental genesis), use it to define a model with focus on Mathematics (one study), use it only in part of the analysis (one study) or do not present evidence about how the model integrate the data analysis (one study).

Most of the studies do not clarify how they assess the teachers' knowledge. In the cases where a questionnaire is used, usually only the structure of the questionnaire is presented, not always discussing the relation of this structure to the TPACK framework. In the case of qualitative studies, some evidence from the data is often presented but, once again, the connection to the model is not always presented.

The studies analyzed intend to assess the teachers' knowledge to integrate technology and, in some cases, to develop that knowledge. One of the studies intends to better understand the TPACK model, analyzing and discussing the relationship between its knowledge domains.

Conclusion

This systematic review intended to achieve a better understanding of the research based on the TPACK knowledge model, trying to get an overview about how the model is being used and the methodological options adopted.

Methodological options assumed

The methodologies adopted seem to be diversified. The options tend to be related to the qualitative or quantitative methodology of the study, with a focus on the use of questionnaires, in the first case, and on interpretative approaches, in the second case. Interpretative approaches tend to be based in observation, interviews and/or document gathering, however, there are also cases where questionnaires are used. The questionnaires, when used, may be aimed at collecting the participants perceptions or measuring their knowledge. The interpretative approaches can be slightly more diversified, but tend to aim the characterization of the teachers' knowledge or the analysis of its development.

The use of the TPACK model

The TPACK model is the most used framework in studies related to the mathematics teachers' knowledge to integrate digital technology. The model is widely used in the research field, however it seems it tends to be used combined with some other(s) framework(s). In the studies analyzed, only one focus directly on the model and its knowledge domains. All the other studies combine it with some additional framework. The development model for TPACK by Niess et al. (2009) and Niess and Gillow-Wiles (2017) and its five levels – recognizing, accepting, adapting, exploring, and advancing – is broadly used. Some other studies try to combine it with the instrumental approach. Some studies combine different frameworks and try to create a theoretical background to support the analysis. In some cases, it becomes difficult to recognize the contribution of the TPACK model. In one of the studies, the TPACK model is used only in part of the study. And in other case, the model

is used in a general way, as an idea of what the teachers' need to know to integrate the technology into their practices, and not with focus on the different knowledge domains of the model.

One significative difference between the studies analyzed is related to the methodology and the instruments used. In some cases, only the teachers' perceptions about their professional knowledge are collected (mainly in studies using questionnaires, but also in data collections based on interviews). In cases, such as in lesson studies, where the teachers practice is actually considered, it is possible to gather information about the teachers' knowledge and not only their perceptions about it.

Final comments

This is a very preliminary systematic review, focusing on the use of the TPACK model to investigate about teachers' integration of technologies and based on a search in Scopus database. It would be important to reflect on the search options and to enlarge the review considering other databases such as the Web of Science. The preliminary results give us information about the methodological options adopted and about how the TPACK model is being used. It would be important to deepen this work to better understand the usefulness of the model and the way how it is combined with other frameworks.

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