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The Mobilization of Technological Pedagogical Content Knowledge: a study conducted with Elementary School Mathematics teachers

Gícia Cavalcanti de Brito[i]
University of Pernambuco, Petrolina, PE, Brazil
Ernani Martins dos Santos[ii]
University of Pernambuco, Petrolina, PE, Brazil

Abstract
Teaching constantly faces challenges driven by the increasing access to Digital Information and Communication Technologies (DICT), which have also brought about significant changes in curriculum organization since the approval of the Brazilian National Common Core Curriculum (BNCC). From this perspective, this study sought to gain a better understanding of the knowledge required for teachers to incorporate technologies into their teaching practices through Technological Pedagogical Content Knowledge (TPACK). This study aims to analyze how elementary school Mathematics teachers mobilize Technological Pedagogical Content Knowledge in lesson planning involving digital technologies. The data, collected through triangulation using a questionnaire, lesson plans, and semi-structured interviews, and analyzed in the light of Bardin's (2011) content analysis, revealed that the teachers did not simultaneously integrate the knowledge bases of the theoretical model. These limitations were mainly attributed to the lack of continuing professional development.

Keywords
Technological Pedagogical Content Knowledge; Brazilian National Common Curricular Base; Digital Information and Communication Technologies; lesson plan; teaching.

A mobilização do Conhecimento Tecnológico Pedagógico do Conteúdo: um estudo com professores de Matemática do Ensino Fundamental

Resumo
A docência enfrenta constantemente desafios impulsionados pelo crescente acesso às Tecnologias Digitais de Informação e Comunicação, que, inclusive, irromperam com importantes elementos da organização dos currículos desde a homologação da Base Nacional Comum Curricular. Sob esse viés, buscou-se, por meio do Conhecimento Tecnológico Pedagógico do Conteúdo, uma melhor compreensão dos conhecimentos necessários para os professores incorporarem as tecnologias às práticas de ensino. Este estudo tem como objetivo analisar como professores de Matemática do Ensino Fundamental mobilizam o Conhecimento Tecnológico Pedagógico do Conteúdo no planejamento de aulas com tecnologias digitais. Os dados reunidos de forma triangulada, por meio de questionário, plano de aula e entrevista semiestruturada, tratados à luz da análise de conteúdo de Bardin (2011), evidenciaram que os docentes não integravam simultaneamente os conhecimentos-base do referido modelo teórico, sendo as limitações atribuídas, principalmente, à falta de formação continuada.

Palavras-chave
Conhecimento Tecnológico Pedagógico do Conteúdo; Base Nacional Comum Curricular; Tecnologias Digitais de Informação e Comunicação; plano de aula; ensino.

La movilización del Conocimiento Pedagógico Tecnológico del Contenido: un estudio con profesores de Matemáticas de la enseñanza primaria

Resumen
La enseñanza se enfrenta constantemente a desafíos derivados del creciente acceso a las Tecnologías Digitales de la Información y la Comunicación, que incluso han transformado elementos importantes de la organización curricular desde la aprobación del Currículo Común Nacional. Desde esta perspectiva, este estudio buscó, a través del Conocimiento Tecnológico Pedagógico del Contenido, comprender mejor los conocimientos necesarios para que los docentes incorporen las tecnologías en sus prácticas de enseñanza. El objetivo de este estudio es analizar cómo los maestros de Matemáticas de primaria movilizan el Conocimiento Tecnológico Pedagógico del Contenido en la planificación de clases utilizando tecnologías digitales. Los datos, recopilados mediante triangulación a través de cuestionarios, planes de clase y entrevistas semiestructuradas, analizados con el análisis de contenido de Bardin (2011), revelaron que los docentes no integraron simultáneamente los conocimientos fundamentales de este modelo teórico, con las limitaciones atribuidas principalmente a la falta de formación continua.

Palabras clave
Conocimiento Pedagógico Tecnológico del Contenido; Base Curricular Nacional Común; Tecnologías Digitales de la Información y la Comunicación; plan de lección; enseñanza.

1 Introduction

The growing access to Digital Information and Communication Technologies (DICT) has encouraged researchers from different fields to understand the impact these technologies have on the teaching and learning processes. As argued by Nakashima and Piconez (2016), the main rationale lies in identifying essential elements for a pedagogical approach that harnesses the potential of new technologies in support of education and teacher training.

According to Brito (2022), Brito and Santos (2023), Koehler, Mishra and Cain (2009), Mishra and Koehler, (2006), these studies have shown that new technologies reshape the ways of teaching and learning. However, this requires changes in the teacher's ways of thinking and acting, especially when the focus is on having students create with or from different technologies, one of the aims of the fifth general competence of the Brazilian National Common Core Curriculum (BNCC) (Brasil, 2017).

The regulatory guidelines regarding the integration of digital technologies into teaching require an in-depth understanding of the types of knowledge mobilized by teachers so they can plan and implement pedagogical practices consistent with this competence. Approaches to Technological Pedagogical Content Knowledge, internationally known as TPACK, argue that the integration of three knowledge domains: disciplinary content knowledge, pedagogical content knowledge, and technological knowledge helps overcome the challenges of bringing teaching and technology closer together, as proposed by Cibotto and Oliveira (2013), Mishra and Koehler (2006). In this sense, adopting TPACK as a theoretical framework could enable the use of technological resources in accordance with the guidelines of the BNCC. Considering that this curriculum-guiding document emphasizes the incorporation of these tools into teaching practice across all curricular components and educational modalities, the central objective of this study is to analyze how Mathematics teachers in the final years of Elementary School, in the municipality of Afrânio, Pernambuco (PE), mobilize TPACK when planning lessons with digital technologies.

Following the approval of the BNCC, it becomes necessary to broaden the analytical perspectives on teachers' professional knowledge, since Alves and Santos (2024), Mishra and Koehler (2006), Queiros et al. (2024), and Shulman (1986) argue that a teacher's knowledge base directly influences the quality of their professional practice. Thus, TPACK presents itself as a pathway to address curricular changes in a context of increasing dissemination of digital technologies, since it is composed of three central components which, when mobilized, can enrich pedagogical practice and promote more meaningful learning.

The theoretical model proposed by Mishra and Koehler (2006) serves as a reference to support teachers in understanding how Digital Information and Communication Technologies (DICT) should be applied in ways that promote the development of competencies and skills, aligning with the objectives of the BNCC, which include forming autonomous, critical, and ethical individuals capable of using technologies to learn, communicate, and consciously engage with the world. Mastery of TPACK also enables teachers to teach curricular content by integrating it with pedagogical techniques and instructional methods through the appropriate use of technologies, while taking into account students' real learning needs across different educational contexts.

Mishra and Koehler (2006) add that knowing how to use technologies is not the same as knowing how to teach with them. This distinction emphasizes that 'teaching with technology' goes beyond technical-operational mastery and simplified classroom approaches. In the context of Mathematics, it moves past the mere assimilation of concepts, fostering creative problem-solving, critical thinking, understanding, and connection with real-world contexts. The BNCC reinforces the importance of encouraging students to adopt a critical and reflective stance in various social practices in order to produce knowledge, solve problems, and exercise agency and authorship in both personal and collective life (Brazil, 2017). However, it is acknowledged that using technological resources from this perspective is not a simple task, especially because many teachers did not have educational experiences with these tools during their initial training. According to Cibotto and Oliveira (2013), even those who did have access to technology often encountered it disconnected from curricular content and pedagogical preparation.

Camelo (2020) highlighted that the intersection among content, methodology, and technology is essential in teacher-education processes, and technological knowledge alone is not sufficient if it is not accompanied by careful pedagogical planning that guides the practical application of these tools in the classroom. Planning, therefore, regarded as a guide for teaching practice, should be seen as the first step toward implementing changes involving digital information and communication technologies (DICT). Assigning new approaches and roles to technologies without prior reflection on their application tends to be ineffective.

During the planning stage, teachers have the opportunity to rethink new proposals and ways in which students construct knowledge, a moment in which the elements of TPACK may emerge and intertwine. This process helps teachers prepare their lessons in accordance with the BNCC guidelines, especially in the Mathematics component.

1.1 An "Enter" into the BNCC: What Is Proposed for the Integration of Digital Information and Communication Technologies into the Mathematics Curriculum

The BNCC states that all schools and teachers must integrate digital information and communication technologies into the curriculum in order to meet new educational and social demands. In Mathematics education, these tools are presented as important elements for understanding reality and for expanding ways of thinking mathematically far beyond numerical calculations.

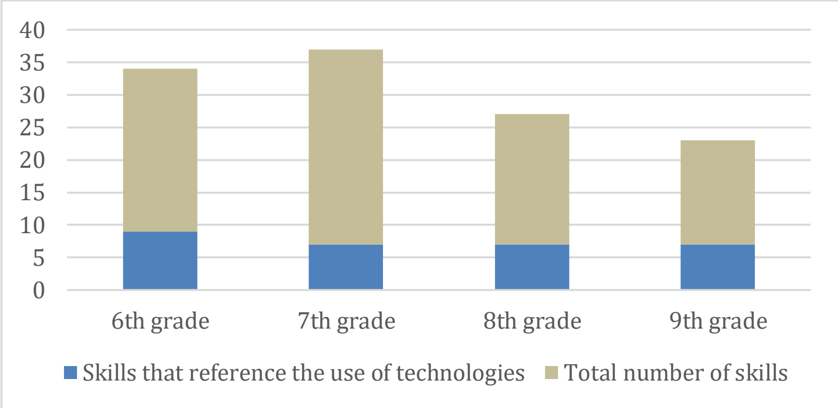
This perspective contrasts with the former view that Mathematics consisted of a rigid body of knowledge to be transmitted and memorized, as the BNCC proposes that mathematical knowledge should be constructed through practical activities that encourage reflection and interpretation as a means of understanding and transforming reality (Brazil, 2017). Digital technologies are no longer treated merely as accessory tools; instead, they are placed at the service of learning, helping to solve problems both within and beyond school contexts.

In Mathematics, among the eight specific competencies for Elementary Education, the fifth explicitly highlights the use of ICT, suggesting that students employ "[…] mathematical processes and tools, including available digital technologies, to model and solve everyday, social, and interdisciplinary problems, validating strategies and results" (Brazil, 2017, p. 265).

This competency aims to develop students who are able to use ICT to construct their own knowledge, encouraging them to identify problems and translate them into mathematical models in order to apply operations and concepts to find solutions. Modeling does not involve merely applying formulas; it also requires critical reflection on the strategies used, the validation of results, and adjustments to the models, enabling students to adopt a critical stance and reflective thinking through the interaction between theory and practice.

The BNCC organizes the Mathematics curriculum for the final years of Elementary Education into 121 skills, with 34 for the 6th grade, 37 for the 7th grade, 27 for the 8th grade, and 23 for the 9th grade, as detailed in Graph 1. References to the use of technologies appear both directly, with explicit indications of tools such as calculators, electronic spreadsheets and software, and indirectly, without specifying the technology to be used in the exploration of mathematical concepts.

Graph 1 – Comparison between the total number of Mathematics skills and those specifically related to the use of digital technologies in the final years of Elementary Education



Source: Brito (2022).

In Graph 1, we observe that the skills related to the use of digital technologies are present in all grades, with nine in the 6th grade and seven in each of the remaining grades. Although ICT appears in a relatively limited way, it is proposed positively, with the aim of expanding the knowledge students already possess by encouraging participation, creation, interaction, and reflection between technology and the content taught through it.

These aspects highlight that the emphasis of teaching practices is directed toward mathematical literacy, defined in the document as:

> [...] the competencies and skills to reason, represent, communicate, and argue mathematically, in order to support the development of conjectures, the formulation and resolution of problems in a variety of contexts, using mathematical concepts, procedures, facts, and tools (Brasil, 2017, p. 266).

Working from this perspective presupposes creating instructional conditions that make Mathematics meaningful in its real-world use, where it is not enough to merely learn concepts and arrive at quick and correct answers. It also requires developing in students the ability to formulate hypotheses, justify and explain how they arrived at their answers, thereby fostering reasoning, critical thinking, and creativity in solving problems applicable to their reality.

In the development of mathematical literacy, students are challenged through the use of technology to understand and apply mathematical reading and writing practices to solve everyday problems, such as reading and interpreting graphs and tables, making estimates, interpreting basic expense statements, among other actions related to the different situations in which Mathematics is used socially. Along this path, the intention is to help students realize that what they learn in school is meaningful to their lives; however, for the use of ICT in Mathematics teaching to be effective, teachers should focus on the process of knowledge construction rather than on the technologies themselves. It is essential to know how to use these tools in ways that meet the specificities of each thematic domain (numerical, algebraic, geometric, etc.), helping students develop mathematical knowledge and achieve the competencies and skills defined by the BNCC. This is a challenge to be addressed.

Three increasingly necessary actions are listed below. These actions require teacher planning before being incorporated into practice and depend on the mobilization of a set of knowledge, such as TPACK, namely: acquiring the ability to represent content and concepts using technology; applying pedagogical strategies that use it constructively; and resorting to technology to facilitate the understanding of concepts considered complex by students, thereby helping them construct their own knowledge.

1.2 A necessary connection: TPACK and lesson planning

In the 1980s, teaching began to be understood as a profession grounded in specific knowledge, driven by studies developed at the international level, more precisely, through the work of Lee Shulman (1986, 1987). Shulman sought to understand the genesis of teaching activity and proposed the systematization of a set of knowledge bases. Originally, the Knowledge Base for teaching, highlighting Pedagogical Content Knowledge (PCK), which concerns the ways of presenting content and transforming it into learning.

This category influenced several researchers, including Mishra and Koehler (2006), who broadened the analytical perspectives and began to incorporate a third element into Shulman's PCK: technological knowledge. Thus, two decades later, TPACK emerged as a theoretical model for thinking about the knowledge required of teachers for the integration of technologies into teaching practices. Moreover, it has also made significant contributions to the field of teacher education, becoming an increasing focus of

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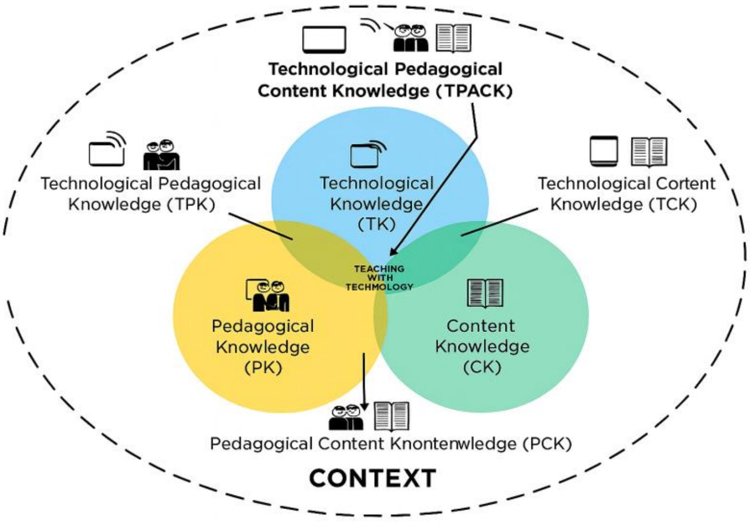
investigation among researchers such as Camelo (2020), Costa and Prado (2015), Pinheiro (2020), Silva, A.(2021), Silva, W. (2018) and Valle (2020).

TPACK, or "Teaching with Technology," known in the international literature as *Technological Pedagogical Content Knowledge*, is composed of three core elements: (1) Content Knowledge (CK), which refers to knowledge of the curricular subject area related to the teacher's field of training; (2) Pedagogical Knowledge (PK), which encompasses knowledge of teaching processes, practices, methods, and strategies; and (3) Technological Knowledge (TK), which concerns knowledge of technologies and their instructional applications, as illustrated in Figure 1

Figura 1 – The Structure of "Teaching with Technology": TPACK and its Knowledge Components



Source: Koehler, Mishra, and Cain (2009) – Adapted by the authors (2024).

From the figure, one can observe the development of new types of knowledge resulting from the pairwise combination of the CK, PK, and TK elements: knowing the content to be taught is fundamental. However, it is essential to identify the most effective approaches to student learning by selecting the most appropriate methodology, as reflected in PCK, which represents the intersection between CK and PK. Moreover, knowledge and use of technological resources are important, but they are insufficient if they are not associated with appropriate methodology and effective representations between resources and content, as indicated at the intersections between TK and PK, as well as between TK and CK, which give rise to Technological Pedagogical Knowledge (TPK) and Technological Content Knowledge (TCK), respectively.

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TPACK results from the intersection of the three core elements of the knowledge base and, according to Camelo (2020), consists of the knowledge required for teachers to transform the subject matter they teach into knowledge through concepts, representations, pedagogical techniques, and the use of technology with predefined pedagogical purposes.

The importance of TPACK in the educational process is evident. Its application enables teachers to transform knowledge into effective pedagogical practices, adapting it to specific teaching and learning contexts, as illustrated by the dashed circular line in Figure 1. These contexts include the structural conditions of schools, teacher education, students' sociocultural experiences, among other factors that impact the effective use of technologies.

As stated by Pinheiro (2020), for high-quality teaching, it is essential to cultivate a contextualized understanding of the complex interactions among TK, PK, and CK and to use this understanding to develop appropriate, context-specific strategies and representations. This means that, when designing their lessons, teachers must consider the different situations in which students are situated within the school reality. For example, a teacher's practice in contexts where students have access to the internet and to different devices for research will differ from that in which students need to go to a computer lab and share computers in order to carry out an activity. According to Valle (2020), the knowledge to be drawn upon will be quite different in these two contexts, and this alters the structure of lesson and activity planning.

School practice with the integration of digital technologies is intrinsically related to the development of effective planning, which is an essential tool for supporting and organizing educational activities, providing guidance, clarity, and purpose to the teacher's actions. Thus, the mobilization of TPACK begins in the planning stage, so that the use of pedagogical resources is viewed as an ally in the teaching and learning processes, as highlighted by Silva (2018).

Silva (2018) further adds that this choice should not be made randomly, but rather should be linked to an educational purpose, with well-defined methodology and objectives for the development of mathematical content, contributing to the development of skills, including digital ones, and of the competencies established by the BNCC.

As proposed by Mishra and Koehler (2006) and Koehler, Mishra, and Cain (2009), TPACK is associated with the action of "teaching with" technology, as it brings together the set of knowledge required for teaching curricular content through pedagogical strategies supported by the integration of technologies, enabling differentiated instruction aligned with students' learning needs. In addition to "teaching with" technology, Costa and Padro (2015) and Silva (2021) highlight that TPACK also allows teachers to "create with" and "reason with" technologies. Each of these actions may be present in the planning process, depending on the role assigned to digital information and communication technologies (TDIC).

When "creating with" technology and articulating TPK, teachers develop the ability to select tools based on their functionalities, pedagogical strategies, and potential uses. From the perspective of Mishra and Koehler (2006), this involves not only the selection of technologies, but also the consideration of the learning context, appropriate mediation, the organization of activities that foster the desired skills, and the selection of the technological resources necessary to achieve these objectives.

"Reasoning with" technology is associated with TCK and fosters an understanding of how a specific technology influences the comprehension of knowledge objects, that is, how teachers perceive the ways in which the approach to mathematical content is transformed through the use of a given technology, as outlined by Costa and Padro (2015).

Thus, the importance of recognizing these elements in teachers' planning is highlighted, since TPACK has been consolidated as a model that makes it possible to assess whether teachers are able to move beyond simplified approaches when planning and teaching with digital technologies. At a time of such significant curricular changes in Elementary Education, these considerations become both relevant and essential to be observed and investigated.

2 Methodological procedures

The research strategy adopted a case study as its methodological procedure, conducted in public school in the municipal school system in Afrânio, a city located in the

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semi-arid region of the state of Pernambuco, Brazil. This study, which represents a subset of a master's research project, focused on the planning of the teaching practice of two Mathematics teachers from the final years of Elementary Education during the first semester of the 2022 academic year, as only these teachers participated in all stages of the research and met the established inclusion and exclusion criteria.

Mathematics teachers who worked in regular classes in the final years of Elementary Education, had specific academic training in the field, and reported routinely integrating the use of digital information and communication technologies (DICT) into their pedagogical practices and lesson plans, were included in the study. Teachers with less than six months of experience at the school (as they were still in the adaptation process), those who were away from their duties (in order to ensure that the analyzed lesson plans reflected actual teaching practice), and those who did not participate in all data collection instruments, were excluded.

To understand what the teachers knew, how they used digital technological resources in their classes, and, above all, whether the digital technology employed served the learning of knowledge objects and the development of skills and competences in accordance with the BNCC framework, three data collection instruments were defined: an online questionnaire, a lesson plan, and a semi-structured interview.

First, an online questionnaire consisting of 30 open- and closed-ended questions was administered to all participants in order to characterize them in terms of personal data, academic background, teaching experience, in-service training, the use of digital information and communication technologies (DICT) in their personal and professional lives, and their knowledge of DICT as addressed in official documents. Subsequently, lesson plans were collected, which constitute the main instrument for the systematization and organization of professional practice and, according to Harris and Hofer (2011), they are considered a valid instrument for assessing teachers' TPACK, since teachers' knowledge is primarily mobilized during the planning process. Finally, semi-structured interviews were conducted individually with the participating teachers, based on the observations of these lesson plans.

The content analysis approach proposed by Bardin (2011) was employed to process and analyze the collected data. The data presented were constructed through the triangulation of the results obtained from the three instruments (questionnaire, lesson plans, and interviews). The participating teachers were identified in the analysis by the pseudonyms Java and Emoji.

This integrated data collection approach, strengthened by its articulation with the theoretical framework, allowed for a deeper understanding of the observed meanings and the dynamics of the phenomenon, thereby contributing to the development of the study's analysis.

3 Results and discussion

In this section, the aim is not to draw comparisons between the two teachers who participated in this study, but rather to present interpretations based on the results obtained, discussing them in light of the theoretical frameworks that underpin the study, with a focus on aspects related to the elements of TPACK in dialogue with the BNCC's propositions regarding the use of digital technologies.

Based on the questionnaire responses, it was observed that the mathematics teachers present very similar professional profiles. Java, aged 34, has been teaching in the final years of Elementary Education for ten years; Emoji, aged 33, has been teaching in the same level of education for eleven years. Both teachers, in addition to having the same field of academic training, completed their undergraduate degrees in 2009 and pursued their studies through a blended distance learning modality. The difference in their years of professional experience is only one year, which indicates a considerable and significant level of experience with this student population. The results presented below show that the teachers demonstrate mastery of PCK, constructed through the articulation between initial teacher education and the experiences accumulated in teaching practice.

Java designed a lesson plan to be applied in the 7th grade, focusing on the knowledge object "Calculation of percentages and simple increases and decreases," selecting the digital calculator and the multimedia projector as technological resources to

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support the development of the following skill: “(EF07MA02) Solve and create problems involving percentages, with a focus on financial education” (Brasil, 2017). Emoji, in turn, directed his lesson plan to the 9th grade, focusing on “Ratio between quantities of different units,” using resources such as the multimedia projector and Google Classroom with the objective of developing the following skill: “(EF09MA07) Solve problems involving the ratio between two quantities of different units” (Brasil, 2017).

Shulman (1986, 1987) emphasizes that teachers’ knowledge for teaching is constructed through the combination of content and pedagogy, that is, what to teach and how students learn. Camelo (2020) states that, over time, this knowledge is consolidated through practical experience. This knowledge, for example, led both teachers to adjust certain strategies, such as review activities, in order to meet the needs of students who had not yet mastered the four basic operations, which are fundamental for learning the knowledge objects addressed in the lesson plans, as reported in the interview.

Although the teachers admitted in the interview that they were not familiar with the BNCC content and followed only the Pernambuco curriculum (Pernambuco, 2017), the lesson plans presented align with the national guidelines. Java conducted the work within the thematic field of “Numbers,” while Emoji focused on the development of algebraic thinking.

Although the teachers mentioned only content knowledge and contextual knowledge as necessary for teaching Mathematics, both adapt different forms of representation and teaching approaches to make the concepts accessible to students, supporting the ideas of Koehler, Mishra, and Cain (2009) and Shulman (1986), which demonstrates the mobilization of PCK.

In the lesson plans, for example, Java proposes the “[...] *problem solving involving percentages and simple increases and decreases in different ways, in addition to the exploration of mental calculation,*” while Emoji, at a certain point, proposes the “[...] *use of a balance scale and objects brought by the students so that they can understand, in practice, what equality between two ratios means*”.

Both teachers continue to articulate PCK while showing concern for connecting these contents to students’ everyday lives, as emphasized by the BNCC (Brasil, 2017). Java addresses the concept of percentage using flyers and store advertisements to

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encourage students to reflect on healthy consumer habits. Meanwhile, Emoji highlights the use of Mathematics in activities related to Physical Education and in the use of the balance scale, encouraging students to think mathematically beyond numerical calculations, once again confirming the presence of PCK in favor of the development of the skills outlined in the BNCC.

While the teachers demonstrate clarity in proposing strategies that lead students to think mathematically in order to solve everyday problems, the same does not occur when technologies come into play. Thus, in the lesson plans, there is no evidence that learning happens through "creating with" technology. According to Costa and Prado (2015), leading students to learn and think with digital technologies is not a simple process, as it requires teachers to engage in new forms of learning and the reconstruction of knowledge from a professional development perspective. Although both teachers selected appropriate digital resources in their lesson plans to support expository teaching and content consolidation, such as slides and video lessons, they still need to recognize the role of technology in the teaching of specific content and explore it for more innovative educational uses This is clearly evidenced in the interview statements, when both professionals mention that the display of video lessons serves solely to provide access to a different approach. Possibly to facilitate content understanding.

Java relies on the use of a digital calculator, whose recommendation is made by the BNCC itself. However, in the lesson plan, it is employed as a strategy to facilitate calculations in the rule of three, given that students show difficulties in mastering mathematical operations, especially multiplication and division. In this situation, the teacher did not go beyond its conventional use to reconfigure this tool for personalized pedagogical purposes (Valle, 2020).

The Google Classroom platform was chosen by Emoji. Regarding this decision, the teacher stated in the interview that it was selected because it is a simple, free, easily accessible tool that is already familiar to students. Nevertheless, he chose to use it solely to make team-based activities/challenges available for later execution in the classroom, using it in a limited manner and without taking advantage of its interactive and collaborative potential. Thus, this is yet another situation in which the action of "creating with" technology is not observed. As stated by Silva (2021), this type of activity fails to take advantage of the pedagogical possibilities of the tool in question, which was, in fact, designed for educational purposes; that is, the teacher did not exploit its capacity to create strategies for teaching with digital technologies. Therefore, these tools cannot be considered as being used from a TPK perspective, as the teachers did not plan to exploit them as spaces for collaborative knowledge construction. Koehler, Mishra, and Cain (2009) argue that TPK involves the transformation of teaching practices through technology, which is not observed in these teachers' approach.

When attention is directed to the knowledge of digital technologies for the construction of learning of specific content, it is observed that, although Professor Java's intention is valid, the calculator is used merely as a tool to perform calculations, rather than as an instrument to promote the construction of mathematical knowledge or to explore relationships among contents in order to test or stimulate students' reasoning, as he himself stated in the interview. For this reason, the action of "reasoning with" technology, which indicates the integration of TCK, is not observed, since, as proposed by Mishra and Koehler (2006), digital technology is not used for the production of knowledge based on prior knowledge nor for the development of new ideas about the content addressed.

This analysis becomes evident when revisiting the strategy presented in the lesson plan, which proposes the "[...] use of a digital calculator to work on the rule of three." In Java's statements during the interview, he reinforces the use of the calculator as a way to familiarize students with different calculation methods and to facilitate their understanding of the rule of three, considering their difficulty in mastering division.

The same occurs when Professor Emoji selects Google Classroom. This platform requires a mediating stance from the teacher and an active posture from the student, leading learners to experience learning situations in non-face-to-face instructional spaces. However, in the lesson plan, its use is limited solely to sending challenges related to ratio and proportion. That is, the depth of the content learned is neither increased nor fundamentally transformed through the use of technology, as noted by Harris and Hofer (2011), thus revealing a misalignment with TCK and with what Mishra and Koehler (2006) indicate regarding the mobilization of this element.

With regard to TPACK and the development of competencies related to digital technologies, Java states, in the questionnaire, that he does not consider himself prepared to use digital information and communication technologies (DICT) in the classroom. In the interview, he reports being unfamiliar with the BNCC and having limited knowledge of the local curriculum that addresses DICT in the final years of Elementary Education. Despite these constraints, he opts to work on a skill that recommends the use of a digital resource, arguing that mobile devices can support students' learning. He further states: "*Today we are in the digital era, right? Cell phones are part of their routine, so we can use this to help them learn. This skill can, indeed, be fully developed, but, in general, that is not always possible* [...]" (Java, individual interview).

Java not only shows openness to incorporating digital technologies but also, indirectly, seeks to work in accordance with the specific Mathematics competency that refers to using available digital technologies to model and solve everyday problems (Brazil, 2017). However, when the teacher intends to select and use technologies, TK appears dissociated from the foundations of PK and CK. According to Mishra and Koehler (2006), teaching based on TK, PK, and CK in isolation is considered unsatisfactory.

Cibotto and Oliveira (2013) emphasize that TPACK emerges as teachers make use of digital technological resources in ways that enable learners to construct and represent mathematical concepts through hands-on experiments and experiences. In contrast to this perspective, the digital calculator is used solely to facilitate the execution of calculations, rather than as a tool for teaching mathematical content itself or for fostering students' logical thinking.

Likewise, the use of slides and video lessons is presented merely as a resource to support or complement the content approach. Therefore, the mobilization of TPACK is not observed in the activities involving technology, since the teacher may appropriate CK and PK but is still unable to interrelate TK with these elements, as discussed by Koehler, Mishra, and Cain (2009) and Mishra and Koehler (2006).

On the other hand, Professor Emoji demonstrates sufficient knowledge of the content to be taught (CK), understands good practices and approaches that enable students to acquire knowledge of ratio and proportion (PK), and shows ease in handling different technologies, and using them for lesson planning. The integration of technologies into their activities, however, assumes a complementary role, without taking advantage of the benefits that tools such as Google Classroom offer for students to construct their own learning.

In the interview, he acknowledges the importance of ICT and points out that this aspect serves as motivation to frequently include it as a teaching resource. However, there is a clear prevalence of the use of the multimedia projector for presenting content and exercises, which he justifies by stating that it is one of the few resources available at the school. Therefore, the teacher's knowledge cannot be characterized as TPACK, since, according to Mishra and Koehler (2006), having operational knowledge does not mean knowing how to "teach with" technology.

Both Emoji and Java point to their own contextual difficulties, such as the lack of technological resources at the school to justify why their practices are limited to the use of the projector and the mobile phone. Regarding this aspect, Java (individual interview) adds: "[...] *Today we live in a technological era, right? Everything today requires technology, but unfortunately this is somewhat removed from our reality. There is not much that can be done. It requires a great deal of resources, and that is not our case."*

For the teachers, this is a factor that directly influences the absence of more effective practices with technology. In addition, the lack of continuing professional development creates difficulties for its use in the classroom. Coincidentally, the respective teachers reported in the questionnaire that they had not participated in continuing education courses on the use of ICT, and stated that the municipal education system rarely offers such training. In this regard, Emoji (individual interview) points out:

> [...] *"The teacher first needs to be 'trained,' right? Because nowadays not everyone has a clear understanding of how to use technology for teaching, right? The first step is indeed to provide proper 'training,' especially since, in most cases, students often know even more than the teacher."*[...].

This aspect may contribute to many teachers still making limited and ineffective use of these tools in the teaching process. We observe that the major challenge is not merely to ensure that technology reaches the classroom, but rather that it arrives "[...] as a tool that enhances learning, and not merely as a simple substitute for other technologies" (Silva, 2018, p. 202).

As argued by Camelo (2020) and Pinheiro (2020), it is pertinent, however, to point out that professional development should address the use of technology not in isolation, but through the mobilization of technological, pedagogical, and content knowledge integrated with one another, as proposed in the TPACK model. Koehler, Mishra, and Cain (2009) highlight that, from the perspective of this theoretical model, teachers gain a deep understanding of how content can change with the application of a specific technology.

High-quality teacher education is essential for quality education. Therefore, the strengthening and expansion of professional development processes grounded in the TPACK framework will become increasingly necessary in the technological landscape.

4 Final considerations

The analysis of the Mathematics lesson plans was challenging due to the specificities of each thematic field and the relationship these fields have with the BNCC and with the integration of ICT, which required a careful and in-depth examination based on the theoretical model. The fact that TPACK is presented in broad terms did not compromise the analysis, since the lesson plans and the teachers’ statements clearly evidenced the presence or absence of its constituent elements. Furthermore, the knowledge of the teachers’ profiles, obtained through the questionnaire, made it possible to identify the influence of these factors when designing the lesson plans.

The results revealed that the teachers demonstrate mastery of PCK, influenced by their initial teacher education and professional experience, especially with regard to “what to teach.” However, the “how to teach” revealed a tendency toward lecture-based classes and no integration of technological knowledge. With regard to the BNCC, it was evidenced that the teachers focused on the development of numerical and algebraic thinking in accordance with the guidelines of the Pernambuco curriculum (2017), which is based on the BNCC.

The study identified that the participating teachers make efforts to include ICT in their lesson plans. However, their practices with these resources remain limited to

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traditional uses, without exploring their potential for the development of knowledge and student autonomy.

The lack of simultaneous integration among technological, pedagogical, and content knowledge became evident, and was attributed to factors such as the lack of equipment and continuing professional development. This points to the need for actions to be undertaken by the municipal government, especially in light of the recent curricular changes.

It is emphasized that continuous professional development processes must be considered, as technology is constantly changing. Not only technical and operational mastery of technology should be taken into account, but also the understanding that effective practices with these tools require the appropriation of TPACK, especially because teachers do not perceive TK as a body of knowledge with specific characteristics necessary for teaching with technologies.

TK associated with the foundations of PCK proves to be essential in professional development initiatives, so that teachers can reflect didactically on the potential, limitations, and pedagogical uses of ICT, taking into account the reality of each educational institution and engaging with the propositions of the BNCC in relation to the specificities of each field within the area under investigation.

It is believed that this study offers data and interpretations which, once added to those already existing in the literature, may contribute to the construction and strengthening of professional development initiatives focused on the planning and use of technological resources from the perspective of the TPACK model. An area that is still incipient in national research in Mathematics.

For future investigations, it is recommended that this study be expanded with additional empirical foundations that make it possible to analyze the practical implementation of lesson plans within the thematic fields of Mathematics. Such an expansion would allow for a more in-depth examination of the specificities and particularities of the teaching of this curricular component with regard to the integration of ICT from the perspective of the TPACK model, contributing to filling gaps not addressed by this research and to deepening the understanding of the articulation among content, pedagogy, and technology in teaching practice.

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Gícia Cavalcanti de Brito, University of Pernambuco (UPE), Petrolina Campus, Graduate Program in Teacher Education and Interdisciplinary Practices (PPGFPPI).
[i] https://orcid.org/0000-0002-9628-9499
Master's degree in Education from the University of Pernambuco (UPE) and a specialist in Applied Linguistics in Education from the Northwest of Minas Gerais College (FINOM). Portuguese Language teacher in the Basic Education system of the municipality of Afrânio, Pernambuco.
Lattes: http://lattes.cnpq.br/7841787044228079
E-mail: giciacavalcanti@hotmail.com

Ernani Martins dos Santos, University of Pernambuco (UPE), Mata Norte Campus, Graduate Program in Education (PPGE)
[ii] https://orcid.org/0000-0002-3824-986X
PhD in Cognitive Psychology from the University of Pernambuco (UPE) and Associate Professor at UPE. He is an Associate Professor at UPE, Graduate Program in Education; in the Professional Master's Degree in Inclusive Education Network - PROFEI and Vice-Dean of Undergraduate Studies at the University.
Authorship contribution: Literature review, methodological aspects, and data analysis.Lattes: http://lattes.cnpq.br/2183864514413741
E-mail: ernani.santos@upe.br

DATA AVAILABILITY

The entire dataset supporting the results of this study has been published in the article itself.

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