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Mathematics Teachers' TPACK: Confronting Classroom Challenges in the Digital Era

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ABSTRACT

This study examined mathematics teachers' Technological Pedagogical Content Knowledge (TPACK) in responding to classroom challenges in the digital era. A descriptive qualitative design was employed to explore teachers' perceptions, practices, and contextual experiences when integrating technology into mathematics instruction. Twelve mathematics teachers from different school settings were selected purposively based on their experience in using digital tools for teaching. Data were collected through a structured TPACK questionnaire, semi-structured interviews, and classroom observations. Questionnaire responses were converted into percentages and classified into five categories, while interview and observation data were analysed thematically to clarify and validate the quantitative descriptions. The findings showed that teachers demonstrated strong Technological Knowledge and Content Knowledge. Technological Content Knowledge and integrated TPACK were categorized as very good, with the integrated TPACK score reaching 81.67%. Pedagogical Knowledge, Pedagogical Content Knowledge, and Technological Pedagogical Knowledge were categorized as good. Classroom observations indicated that teachers used dynamic geometry software, graphing tools, spreadsheets, interactive whiteboards, and real-time assessment applications to support visualization, exploration, collaboration, and formative assessment. Nevertheless, several challenges remained, including unstable infrastructure, technical disruptions, uneven student digital literacy, limited preparation time, classroom management, and the difficulty of aligning technology with specific mathematical concepts and pedagogical purposes. The findings indicate that technology proficiency alone does not guarantee meaningful integration. Continuous, context-sensitive professional development is therefore needed to strengthen pedagogical adaptation, assessment practices, classroom management, and the consistent alignment of technology, mathematics content, and learning objectives.

ABSTRAK

Penelitian ini mengkaji Technological Pedagogical Content Knowledge (TPACK) guru matematika dalam menghadapi tantangan pembelajaran di era digital. Penelitian menggunakan desain kualitatif deskriptif untuk mengeksplorasi persepsi, praktik, dan pengalaman kontekstual guru ketika mengintegrasikan teknologi ke dalam pembelajaran matematika. Sebanyak dua belas guru matematika dari beragam konteks sekolah dipilih secara purposif berdasarkan pengalaman mereka menggunakan perangkat digital dalam pembelajaran. Data dikumpulkan melalui angket TPACK terstruktur, wawancara semi-terstruktur, dan observasi kelas. Respons angket dikonversi menjadi persentase dan dikelompokkan ke dalam lima kategori, sedangkan data wawancara dan observasi dianalisis secara tematik untuk memperjelas serta memvalidasi deskripsi kuantitatif. Hasil penelitian menunjukkan bahwa guru memiliki Technological Knowledge dan Content Knowledge yang kuat. Technological Content Knowledge dan TPACK terintegrasi berada pada kategori sangat baik, dengan skor TPACK terintegrasi mencapai 81,67%. Pedagogical Knowledge, Pedagogical Content Knowledge, dan Technological Pedagogical Knowledge berada pada kategori baik. Hasil observasi menunjukkan bahwa guru memanfaatkan perangkat lunak geometri dinamis, aplikasi grafik, spreadsheet, papan tulis interaktif, dan aplikasi asesmen waktu nyata untuk mendukung visualisasi, eksplorasi, kolaborasi, dan asesmen formatif. Meskipun demikian, masih ditemukan kendala berupa keterbatasan infrastruktur, gangguan teknis, perbedaan literasi digital siswa, keterbatasan waktu persiapan, pengelolaan kelas, serta kesulitan menyelaraskan teknologi dengan konsep matematika dan tujuan pedagogis tertentu. Temuan ini menunjukkan bahwa penguasaan teknologi saja belum menjamin integrasi yang bermakna. Oleh karena itu, diperlukan pengembangan profesional yang berkelanjutan dan sesuai konteks untuk memperkuat adaptasi pedagogis, praktik asesmen, pengelolaan kelas, serta konsistensi integrasi teknologi, materi matematika, dan tujuan pembelajaran.

INTRODUCTION

Technology has reshaped nearly every aspect of contemporary life, and classrooms are no exception. Over the past two decades, teachers have been increasingly expected to teach content using digital tools, often with limited training and highly variable access to resources. These pressures are particularly acute in mathematics education, as the subject itself presents significant conceptual challenges for many students. One conceptual framework that has emerged as especially relevant for understanding these challenges is Technological Pedagogical Content Knowledge (TPACK).

TPACK, first developed by Mishra and Koehler (2006), describes the knowledge teachers need to teach content in a pedagogically sound way through technology. It involves not only knowing how to use digital tools or understanding the curriculum, but also understanding the complex relationships among technology, pedagogy, and content. As Herring, Koehler, and Mishra (2016) argued, effective TPACK enables teachers to manage the tensions and synergies among these domains rather than treating them as separate concerns. This is especially important in mathematics, where abstract concepts often require creative pedagogical approaches and where technology, when used effectively, can make invisible structures visible (Bakir, 2016; Ghavifekr & Rosdy, 2015; Parpieva et al., 2020).

TPACK has been linked to higher student engagement in mathematics. For example, Niess (2011) found that teachers with stronger TPACK created classrooms in which students were more engaged and developed better conceptual understanding. Dynamic geometry tools, for instance, allow students to interact directly with shapes and observe transformations in real time, which is difficult to achieve through traditional methods alone. Harris, Mishra, and Koehler (2009) extended this argument by suggesting that well-developed TPACK can promote not only content mastery but also the critical and digital thinking skills students need beyond formal schooling.

Indonesia is a particularly important and challenging context for this issue. Although there is a strong national commitment to improving educational quality, the country's school system is characterized by deep structural inequalities (Wijaya et al., 2021). The digital divide between urban and rural areas remains a persistent problem. Many schools outside major cities do not have reliable internet connections, functioning computers, or access to educational software (Kartiasih et al., 2022). Even where technology is available, teachers frequently report that they have not received meaningful training in how to use it for instructional purposes, much less how to integrate it with both content and pedagogy.

Cultural and pedagogical traditions also play an important role. The historical emphasis on memorization and procedural practice in Indonesian mathematics instruction can make it difficult for teachers to imagine, or justify, more open-ended, technology-supported approaches. When TPACK requires approaches that differ substantially from what teachers experienced as students, resistance is understandable, even if it may ultimately limit instructional innovation.

Content knowledge adds another layer of complexity. In under-resourced settings in particular, some teachers may have limited familiarity with advanced mathematical ideas, which can restrict their ability to use technology meaningfully. If a teacher does not fully understand the concept of a function, for example, it is difficult to use graphing software in ways that genuinely deepen students' understanding rather than merely producing visually appealing graphs. Given this context, a closer examination of how Indonesian mathematics teachers experience and assess their own TPACK is warranted. This study does not aim to produce broad generalizations; rather, it seeks to identify, with contextual specificity, where teachers' strengths lie and where gaps remain so that professional development efforts can be more precisely targeted.

METHOD

This study employed a descriptive qualitative approach, which was appropriate for exploring how teachers understood and experienced their own competence in relation to TPACK. Rather than testing a hypothesis or measuring TPACK against an external standard, the study aimed to examine teachers' perceptions, classroom practices, and contextual challenges. Qualitative approaches are well suited to this type of inquiry because they allow for nuance, ambiguity, and contextual interpretation in ways that purely numerical surveys cannot (Sandelowski, 2000).

Twelve mathematics teachers working in a range of school settings participated in the study. They were selected purposively, with the main criterion being that they had some experience integrating digital tools into their teaching. They did not necessarily have extensive experience, but they had sufficient exposure to form informed views about what technology integration involved. In qualitative research, sample size is less concerned with statistical representation than with the depth and variety of insights participants can provide (Creswell, 2013). The teachers came from different professional backgrounds and school contexts, which enriched the data.

Two main approaches were used to collect data. First, teachers completed a structured questionnaire in which they rated their competence across the TPACK dimensions (TK, CK, PK, PCK, TCK, TPK, and TPACK as a whole). These self-assessments provided a broad picture of the areas in which teachers felt confident and those in which they felt less confident. Second, semi-structured interviews were conducted to explore the questionnaire results in greater depth. The interviews were open-ended, and teachers were asked to describe specific situations, explain their thinking, and reflect on the difficulties they faced. As recommended by Kvale and Brinkmann (2009) and Merriam and Tisdell (2016), this approach allowed the researcher to follow unexpected themes rather than being restricted by a predetermined script.

The data were analyzed using the thematic analysis approach described by Braun and Clarke (2006). Questionnaire responses were coded according to the TPACK domains and subsequently grouped into broader themes that emerged from the data. Interview transcripts were analyzed in conjunction with the questionnaire data, often revealing the reasoning or experiences behind particular ratings. Questionnaire scores were converted into percentages using the following formula:

$$\text{Percentage score } (\%) = \frac{\text{score obtained}}{\text{max score}} \times 100\%$$

The data obtained were then grouped into the categories shown in Table 1 (Sugiyono, 2013).

Table 1. Category Groups

Range (%)	Interpretation
0-20	Very Poor
21-40	Poor
41-60	Fair
61-80	Good
81-100	Very Good

The categories emerging from the questionnaire analysis were then further explored and validated through the interview data, providing a richer and more detailed understanding of participants' TPACK in confronting classroom challenges in the digital era.

RESULTS AND DISCUSSION

Before discussing the questionnaire data, it is important to describe the classroom contexts observed during the study. Overall, the classrooms were orderly and purposeful, not in a rigid or authoritarian sense, but in the sense that teachers had established routines and relationships that supported learning. Desks were frequently arranged in clusters rather than rows, encouraging students to communicate and collaborate. The classroom spaces were decorated with student-created posters, pictures, and mathematical vocabulary, suggesting that they were actively used to support learning.

Technology was present in most classrooms; some had interactive whiteboards, while others had computers. What stood out was how teachers moved around the classroom: they circulated regularly, stopped beside individual students or small groups, checked work, asked questions, and occasionally redirected students' attention. This kind of active monitoring is not always associated with technology-rich classrooms, but it was consistently observed. Students also appeared comfortable asking questions and working through confusion aloud, which is particularly important in contexts where mathematics has often been experienced as high-stakes and anxiety-inducing.

In terms of instructional approach, the teachers observed did not rely on a single method. Lessons typically moved through several phases, including an introduction, guided practice, and collaborative or exploratory activity. Technology appeared at different points depending on the teacher's instructional goals. For instance, in a lesson on geometric transformations, a teacher used dynamic geometry software to demonstrate what happens to a shape when it is translated, rotated, or reflected. Students were then asked to perform the same operations, predict what would happen before each transformation, and check their intuitions. Such immediate visual feedback is difficult to achieve through static diagrams alone.

Graphing tools in algebra classes helped make the connection between an equation and its graph more concrete in ways that are difficult to achieve through symbolic manipulation alone. Real-time polling and quiz tools were also used in some classrooms to check students' understanding during lessons rather than waiting until a formal test.

However, it would be misleading to present an entirely uniform picture. Not all lessons used technology with equal purpose, and technical problems sometimes interrupted the flow of instruction. Although these interruptions were relatively minor, they were noticeable and appeared to disrupt the concentration of both teachers and students for short periods.

Student engagement was noticeably higher during lessons that incorporated interactive technology. The difference was not dramatic, but it was evident in the way students leaned forward, asked spontaneous questions, and persisted with tasks they found confusing. A statistics lesson was particularly illustrative: students used spreadsheet software to analyze data they had collected from a simple classroom survey. As they moved between the data and their conclusions, identified their own errors, and corrected them, they demonstrated a form of mathematical agency that is not always easy to cultivate.

At the same time, a few students in each class struggled with the digital tools themselves, including navigating unfamiliar interfaces, losing data, and not knowing how to recover from errors. This finding serves as a practical reminder that technology integration does not automatically benefit every learner equally. Attention to digital literacy alongside mathematical content is therefore part of what effective TPACK requires.

Several recurring challenges emerged across the observations and interviews. Technical failures were the most immediately visible: devices failed to connect, software crashed, and projectors did not function as expected. These problems consumed instructional time and, in some cases, unsettled teachers who had planned carefully around specific tools. Although the need for reliable infrastructure and responsive technical support is not new, it remains unmet in many schools.

A less visible but arguably more significant challenge concerned pedagogical fit. In some lessons, technology was present but did not appear to add substantial instructional value. It was used because it was expected, rather than because it made the mathematics easier to understand or more meaningful to explore. Distinguishing between using technology and using it well requires time, reflection, and, ideally, a professional learning community. Several teachers reported needing more time to experiment with new tools before using them in class, a need that current working conditions rarely accommodate.

TK, or teachers' familiarity with technology, is in some ways the most basic dimension of TPACK, but it is not trivial. A teacher who is uncomfortable with technology or lacks the skills to recover from common problems cannot integrate technology effectively, regardless of how strong their content and pedagogical knowledge may be. Wiguna et al. (2017) described TK as encompassing a range of abilities, from basic tool use to more advanced digital capabilities, with the educational significance of any particular tool depending on how it is deployed (Koehler & Mishra, 2009).

Table 2. Technological Knowledge of Mathematics Teachers

Item	Percentage	Interpretation
I know how to solve my own technical problems.	91,67%	Very Good
I can learn technology easily.	81,67%	Very Good
I keep up with important new technologies.	85,00%	Very Good
I frequently explore technology.	95,00%	Very Good
I know about a lot of different technologies.	81,67%	Very Good
I have the technical skills I need to use technology.	83,33%	Very Good

The TK results in Table 2 are among the strongest in this study. Overall, almost all teachers rated themselves in the "Very Good" range on every item, indicating a confident and adaptable relationship with technology. The troubleshooting item is particularly notable: 91.67% of participants felt capable of solving their own technical problems. This has practical importance because a teacher who can quickly recover from a technical failure does not need to abandon an entire lesson plan when something goes wrong.

Perhaps the most notable figure is the 95.00% of teachers who reported frequently exploring technology outside formal training contexts. This suggests intrinsic curiosity rather than a compliance-based approach to digital tools, which is generally a better predictor of meaningful classroom integration than externally mandated training alone (Hew & Brush, 2007). The adaptability reflected in these scores learning quickly and keeping up with new developments is particularly important given the rapid pace of change in the educational technology landscape.

However, high self-assessed TK does not guarantee that this knowledge is being applied effectively in teaching. The relationship between knowing how to use tools and using them in pedagogically productive ways is precisely the challenge that the other TPACK dimensions capture. Continued engagement with professional development remains important not because teachers lack ability, but because the field continues to change (Ertmer & Ottenbreit-Leftwich, 2010; Mishra & Koehler, 2006).

Content knowledge is foundational. A teacher who does not understand the mathematics being taught will struggle to use technology purposefully because they cannot evaluate whether a particular representation or tool actually illuminates the concept in question or merely produces an impressive visual (Shulman, 1986; Ball et al., 2008).

Table 3. Content Knowledge of Mathematics Teachers

Item	Percentage	Interpretation
I have sufficient knowledge about mathematics.	83,33%	Very Good
I can use a mathematical way of thinking.	83,33%	Very Good
I have various ways and strategies of developing my understanding of mathematics.	85,00%	Very Good

Participants' self-assessments of CK (Table 3) were strong across all items, with all three reaching the “Very Good” category. A total of 83.33% of participants reported that their mathematical knowledge was sufficient, and the same proportion described themselves as capable of mathematical thinking, including reasoning, conjecturing, and making connections rather than merely executing procedures (Schoenfeld, 2011). In addition, 85.00% reported using various strategies to develop their own mathematical understanding, suggesting ongoing engagement with the discipline rather than reliance solely on what was learned during initial training.

These figures are encouraging because CK is not static. Mathematics continues to evolve, and connections between school-level content and more advanced ideas matter for how teachers explain and explore mathematical concepts. Teachers who continue developing their mathematical understanding tend to provide richer and more connected explanations to students (Ma, 1999; Hill et al., 2005). The commitment reflected in the 85.00% figure is therefore an important asset.

Professional development programs designed to support TPACK should not overlook CK. It is tempting to focus on the technological component of TPACK because that is where change often appears most urgent, but improving teachers' mathematical understanding can have ripple effects across all other dimensions (Darling-Hammond et al., 2017).

PK describes a teacher's command of teaching as a professional practice, including how to structure lessons, respond to misunderstanding, create a productive classroom environment, and assess what students actually understand rather than what they can merely recall (Shulman, 1986). It is less domain-specific than CK but equally foundational.

Table 4. Pedagogical Knowledge of Mathematics Teachers

Item	Percentage	Interpretation
I know how to assess student performance in a classroom.	78,33%	Good
I can adapt my teaching based upon what students currently understand or do not understand.	76,67%	Good
I can adapt my teaching style to different learners.	80,00%	Good
I can assess student learning in multiple ways.	75,00%	Good
I can use a wide range of teaching approaches in a classroom setting.	80,00%	Good
I am familiar with common student understandings and misconceptions.	76,67%	Good
I know how to organize and maintain effective classroom management.	75,00%	Good

The PK results (Table 4) present a slightly different pattern from TK and CK. All items fell within the “Good” range. This may reflect the nature of pedagogical knowledge: it is more difficult to develop in isolation than technological skills, and it is highly dependent on accumulated classroom experience and feedback. A teacher can experiment with new software independently, but genuine adaptive teaching skill requires practice in authentic classroom interaction.

Scores for classroom management and multi-method assessment (both 75.00%) were among the lowest items. These are areas in which structured professional support, such as coaching, peer observation, and guided reflection, tends to be more effective than self-directed learning alone. Adapting instruction to diverse learners and using a range of teaching approaches (both 80.00%) were stronger, possibly because these competencies are addressed more explicitly in effective initial teacher education programs.

Recognizing student misconceptions is particularly important in mathematics. Smith et al. (1994) showed that mathematical misconceptions are persistent and systematic; they do not simply disappear with additional practice but need to be addressed directly. Teachers who are familiar with common conceptual stumbling blocks are better positioned to design instruction that anticipates and challenges these errors rather than inadvertently reinforcing them (Tomlinson, 2001; Black & Wiliam, 1998).

Shulman (1986) introduced PCK as the knowledge that distinguishes a subject-matter expert from an effective teacher of that subject. It refers to the capacity to represent content in ways that are comprehensible to learners through analogies, examples, illustrations, demonstrations, and explanations that connect with students' current understanding.

Table 5. Pedagogical Content Knowledge

Item	Percentage	Interpretation
I can select effective teaching approaches to guide student thinking and learning in mathematics.	80,00%	Good

Based on Table 5, eighty percent of participants rated themselves as "Good" on PCK. This is encouraging, but it should be interpreted with caution because PCK is difficult to self-assess accurately. What teachers believe they are doing pedagogically and what actually occurs in the classroom do not always align. Although this problem is not unique to PCK, it is particularly significant in this domain.

The classroom observations provided some evidence that these self-assessments were reasonably aligned with practice. Teachers demonstrated awareness of common mathematical difficulties and designed instructional moves to address them. Problem-based and inquiry-oriented approaches appeared in multiple classrooms, and teachers generally attempted to connect new content to students' prior knowledge (Hiebert et al., 1997; Boaler, 2016; Ball, Thames, & Phelps, 2008).

Still, PCK is likely the dimension in which the gap between "good" and "excellent" is most consequential. A teacher who understands not only the mathematics but also how students tend to misunderstand it and who has a repertoire of strategies for addressing those misunderstandings can achieve forms of learning that more technically proficient colleagues may not (Smith et al., 1994; Darling-Hammond et al., 2017). This suggests that PCK should be a priority focus for professional development programs that take TPACK seriously.

TCK represents a form of knowledge that is particularly relevant in the digital age: knowing which technologies are suited to illuminating particular mathematical ideas and being able to use them accordingly (Koehler & Mishra, 2009). A teacher with strong TCK does not simply know how to use GeoGebra in general; they understand that GeoGebra's dynamic features are especially powerful for exploring properties of geometric figures, and they know how to design tasks that leverage those features productively.

Table 6. Technological Content Knowledge

Item	Percentage	Interpretation
I know about technologies that I can use for understanding and doing mathematics.	83,33%	Very Good

Based on Table 6, the 83.33% "Very Good" rating for TCK suggests that these teachers had a solid working knowledge of digital tools available for mathematics instruction. References to GeoGebra, Desmos, graphing calculators, and spreadsheet tools emerged naturally in interviews, usually in relation to specific mathematical topics. This topic-specific and grounded awareness differs qualitatively from general familiarity with technology (Cohen, 1995; Kaput, 1992).

This finding also aligns with the observation data. Teachers generally chose tools that suited the content being taught, such as dynamic geometry software for transformation geometry and graphing tools for functions and algebra, rather than defaulting to the same application regardless of context. At its best, this approach reflects what Drijvers et al. (2010) described as meaningful "instrumental orchestration": integrating technology into the structure of a lesson in ways that serve specific mathematical goals. Whether teachers can consistently achieve this level of intentionality, or whether it varies depending on the topic and context, remains an open question that this study was not designed to fully answer (Ball et al., 2008; Goldenberg & Cuoco, 1998; Hegedus & Moreno-Armella, 2009).

TPK concerns the pedagogical implications of technology choices, not what a tool can do mathematically, but how using it affects how teachers structure activities, manage student work, and scaffold learning (Mishra & Koehler, 2006). A teacher with strong TPK recognizes, for instance, that real-time polling changes the feedback loop in a lesson or that collaborative use of a shared digital document shifts the social dynamics of group work.

Table 7. Technological Pedagogical Knowledge of Mathematics Teachers

Item	Percentage	Interpretation
My teacher education program has encouraged me to think more deeply about how technology could influence the teaching approaches I use in my classroom.	85,00%	Very Good
I think critically about how to use technology in my classroom.	78,33%	Good
I can adapt the technologies I am learning about to different teaching activities.	80,00%	Good
I can select technologies for my classroom that enhance what I teach, how I teach, and what students learn.	80,00%	Good
I can use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework.	80,00%	Good
I can provide leadership in helping others coordinate the use of content, technologies, and teaching approaches at my school and/or district.	80,00%	Good
I can choose technologies that enhance the content for a lesson.	76,67%	Good

The TPK results (Table 7) show a notable pattern: the highest item (85.00%, "Very Good") concerns the influence of initial teacher education on participants' thinking about technology. This suggests that their programs successfully prompted reflection on technology use, even if the day-to-day realities of classroom integration remained more complex. The remaining items clustered around 76.67%–80.00% in the "Good" range, indicating consistent competence with room for further development.

The leadership item at 80.00% is also noteworthy. It suggests that most teachers felt capable not only of integrating technology in their own classrooms but also of supporting colleagues in doing the same. Whether they are given opportunities to exercise that leadership is another matter, and one that school administrators and professional development designers should consider more seriously (Fullan, 2011).

Critical thinking about technology use is perhaps the most important of these items. It marks the difference between adopting a tool because it is available and choosing a tool because it serves a specific instructional purpose. Developing this selective and principled approach to technology takes time and often requires experience with what happens when the wrong tool is selected for a given context (Niess, 2005; Ertmer & Ottenbreit-Leftwich, 2010; Koehler & Mishra, 2009).

TPACK in its integrated form teachers' ability to bring mathematics, pedagogy, and technology together in coherent, well-designed lessons is the central concern of this study. It is a demanding standard. Meeting it does not mean using technology in every lesson or knowing every available tool; rather, it means making principled choices that support mathematical understanding and student learning (Koehler & Mishra, 2009; Mishra & Koehler, 2006).

Table 8. Technological Pedagogical Content Knowledge of Mathematics Teachers

Item	Percentage	Interpretation
I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches.	81,67%	Very Good

Based on Tabel 8, the integrated TPACK score of 81.67% is encouraging because it falls at the lower end of the "Very Good" category, suggesting genuine capacity without overstatement. The classroom observations broadly supported this self-assessment: overall, teachers designed and implemented lessons in which technology played a purposeful rather than decorative role. Students engaged with mathematical ideas through technology rather than merely around it (Hegedus & Moreno-Armella, 2009; Niess, 2005).

What this score does not capture is consistency. A group average of 81.67% does not mean that every lesson, teacher, or topic achieved this level of integration. Some lessons were more technologically rich and pedagogically sophisticated than others, and the reasons for this variation teacher confidence, familiarity with the topic, available tools, and class dynamics warrant further exploration.

These results also align with the conditions for effective professional development described by Darling-Hammond et al. (2017): sustained engagement, an integrated focus on content and pedagogy, and opportunities to try out practices and reflect with colleagues. Teachers who already have a strong foundation, as these participants appeared to have, are likely to benefit substantially from this kind of support.

CONCLUSION

This study sought to understand how a group of Indonesian mathematics teachers experienced their own TPACK, where they felt competent, where they saw room for growth, and what their classrooms looked like when they attempted to integrate technology with mathematics and pedagogy. The findings present a nuanced picture of both strengths and areas for improvement.

Technological Knowledge was clearly a strength. The teachers were curious about technology, comfortable with troubleshooting, and willing to experiment, characteristics that support meaningful integration. Content Knowledge was also very strong, with teachers reporting confidence in their mathematical knowledge and commitment to continued learning. TPACK in its integrated form scored 81.67%, indicating real capacity to bring the three domains together.

Pedagogical Knowledge was the domain most in need of improvement. Scores in the "Good" range indicate competence, but they also suggest that more nuanced, flexible, and student-responsive teaching practices still need to be strengthened. Improving PK, especially in relation to assessment, understanding student misconceptions, and classroom management, would likely have positive effects across all TPACK domains because pedagogy mediates between teachers' content and technological knowledge and what students actually experience.

More generally, this study supports what the literature has long indicated: TPACK is not a static accomplishment but a continuous developmental process. The digital landscape that teachers navigate continues to change, and the pedagogical challenges of mathematics education remain complex. Sustained and targeted professional development grounded in what teachers actually do in their classrooms, not only in what they know in the abstract remains one of the most reliable ways to build and maintain the kind of integrated competence described by the TPACK framework.

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