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Mathematics and science teachers: How their perceptions of their TPACK and use of technology interrelate

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Abstract

The integration of information and communication technology (ICT) in mathematics and science (MAS) classrooms is not yet sufficient despite its advantages. This study investigates the perceptions of MAS teachers on ICT integration for presenting information and visual aids, inquiry, and assessment and compares it with their self-reported technological, pedagogical, and content knowledge (TPACK). The data was collected using an online quantitative questionnaire distributed using non-probabilistic sampling to 91 in-service teachers. The results show that teachers use ICT to a moderate extent for presenting information and for assessment and to a low extent for inquiry. There was a moderate correlation between teachers' perceived TPACK and the extent of their ICT integration, and most frequently used forms of ICT were interactive presentations, video/image/animation, digital games, eBooks, digital practice apps, computerized environments, and widgets. The findings can be translated into practical aspects for implementation in pre- and in-service teacher training.

Keywords: information and communication technology; technology integration, technological pedagogical and content knowledge, in-service teachers

INTRODUCTION

In recent decades, numerous researchers in education have acknowledged the many benefits of using information and communication technology (ICT) for teaching and learning mathematics and science (MAS) (see, e.g., Ball et al., 2018; Chien & Wu, 2020; Drijvers, 2019; Hillmayr et al., 2020; Körtesi et al. 2022; Olsher & Lavie, 2023). However, many suggest that its utilization is far from being effective enough (e.g., McCulloch et al., 2018; Umugiraneza et al., 2018). The bulk of research on ICT integration by MAS teachers predates the COVID-19 pandemic. However, during the pandemic, many teachers were compelled to shift to remote teaching, which involved intensive integration of ICT. In Israel, training sessions were conducted to guide teachers on how to utilize ICT tools for remote teaching, and expert ongoing support was provided. Teachers thus gained access to a wealth of online resources that included technological applications and diverse platforms for managing distance learning.

It might be assumed that, given their experience during COVID-19, teachers would continue to apply this new knowledge and increase ICT integration into their teaching. Therefore, understanding how MAS teachers currently perceive and use ICT and recognizing teachers' pivotal role in successfully incorporating ICT is of paramount importance.

Previous studies that have examined teachers' use of ICT primarily focused on three factors that can facilitate or impede effective ICT integration: teachers' beliefs about teaching with ICT (e.g., Dogan et al., 2021; Joo et al., 2018; Thurm & Barzel, 2022; Yao & Zhao, 2022), their self-efficacy (e.g., Dogan et al., 2021; Yao & Zhao, 2022), and their knowledge (e.g., Joo et al., 2018; Kapici & Akcay, 2019; Yao & Zhao, 2022). This present research

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Contribution to the literature

- This article contributes to the literature by examining MAS teachers' perceptions on ICT integration from three didactical aspects that form a unique combination not previously explored in previous studies: presentation of information and visual aids, inquiry, and assessment (PIA).
- The current study enriches and extends previous knowledge gained relating to teachers' technological, pedagogical, and content knowledge (TPACK) by providing an in-depth examination of its different components and their correlation with teachers' use of ICT for the aspects mentioned above, including which specific ICT tools are used for each.
- The current study identifies five core TPACK items that most correlate with the extent of ICT use. This finding can be transformed into practical aspects for preservice and in-service teacher training.

focuses on three didactical aspects that form a unique combination not previously explored in previous studies, specifically, PIA, but are considered central applications, both according to the authors' experience and according to numerous researchers (e.g., Çalik et al., 2014; Hoyles, 2018; McCulloch et al., 2018; Thurm & Barzel, 2022).

Similar to other notable studies on ICT use by teachers (e.g., Koehler & Mishra, 2008; Mishra & Koehler, 2006; Schmid et al., 2021; Shin, 2021), this study uses the TPACK model to examine teacher knowledge. Note that this study is part of a larger study dealing with MAS teachers' emotions toward the integration of computer technologies and their TPACK. The current study is meant to enrich and extend the knowledge gained from previous studies relating to TPACK by providing an in-depth examination of its different components and their correlation with teachers' use of ICT for PIA, including which specific ICT tools are used for each.

LITERATURE REVIEW

ICT in MAS Teaching

ICT in MAS education is considered very important in international policy and curricula (National Council of Teachers of Mathematics [NCTM], 2008; National Research Council, 2013). Studies indicate that ICT can promote learning in various ways, including dynamically linking various forms of representation and facilitating more constructivist teaching methods (e.g., Ball et al., 2018; Drijvers, 2019; Drijvers et al., 2016; Hillmayr et al., 2020). It offers many diverse benefits: it is especially helpful for students with a visual learning style (Clarke et al., 2006); enhances problem-solving and problem-posing skills, critical thinking, and creativity (Fuchsova & Korenova, 2019; Körtesi et al., 2022); facilitates visualization and usage of different representations (Olsher & Lavie, 2023; Segal et al., 2016); and promotes collaboration and communication (Comi et al., 2017). Students can use ICT to independently explore, discover, and develop MAS concepts (e.g., Çalik et al., 2014; Hoyles et al., 2013; Segal et al., 2016). Additionally, a wealth of available online resources can enrich students' learning experience (e.g., Hoyles et al., 2013). Researchers have also confirmed the positive effect of students' computer experiences on their performance when undergoing technology-based assessment (Chien & Wu, 2020).

However, despite the significant advantages of integrating ICT into MAS teaching and learning, it seems that the expected significant change regarding its incorporation into classrooms has not come about (e.g., McCulloch et al., 2018; Umugiraneza et al., 2018). The reasons for this may be multifaceted, but the consensus is that the teachers are the key factor for successful ICT integration (e.g., Körtesi et al., 2022), and studies have found that both external and internal factors are influential (McCulloch et al., 2018).

Internal factors include teachers' age, seniority, and, in particular, their frequency of ICT use. Studies have shown that age has a negative impact (older teachers tend to use it less: Perienen, 2020; Umugiraneza et al., 2018; Yao & Zhau, 2022); years of teaching experience has an indirect negative impact (Inan & Lowther, 2010), and, in particular, rate of use of ICT has a positive impact (the more teachers use ICT, the more they realize its benefits and increase its use: Perienen, 2020).

External factors include grade taught, school ranking, exposure to ICT in professional development workshops, topic being taught, and instructional goal. Yao and Zhao (2022) found that mathematics teachers at lower grade levels exhibited a higher tendency to incorporate technologies into their lesson preparation and teaching, although this is contrary to the findings of Umugiraneza et al. (2018), who found lower use of ICT in early grades. Teachers from low-ranking schools appear to need more support for ICT integration, and teachers who attend workshops were more likely to use ICT in their teaching than those who do not (Umugiraneza et al., 2018). McCulloch et al. (2018) pointed out the importance that the mathematical topic has in influencing teachers' use of ICT, and Ocak and Baran (2019) noted that the science topic plays a crucial role in selecting the technologies employed during the lesson design phase. Finally, teachers tend to select ICT tools that they perceive are well-aligned with their instructional goals (McCulloch et al., 2018).

Various Ways ICT Can Be Used in Teaching and Learning

Drijvers (2018) distinguished two different goals for using technology when teaching mathematics. The first is mathematical functionality, which differentiates between tools used for specific mathematical subjects, such as "*tools for algebraic work, graphing tasks, statistical analyses*" (Drijvers, 2018, p. 232) and more. The second is didactical functionality, which is particularly related to the "*task and the way in which the tool is used in the teaching and learning process*" (Drijvers, 2018, p. 232).

There are a number of didactical categories of ICT. For example, *tutorial tools* support individual learning practice (Li & Ma, 2010; Thurm & Barzel, 2022). *Presentation technologies* include document cameras, interactive whiteboards (Polly, 2014), and video presentations of experiments on basic science concepts (Sever et al., 2013). Other tools support working with *multiple representations* (Hegedus & Roschelle, 2013; Hoyles, 2018; Thurm & Barzel, 2022). Interspersed among them are those that allow easy simultaneous access to *different forms of representations* (Hegedus & Roschelle, 2013) or those that offer novel representational infrastructures for mathematics so that students "*think with them*" (Hoyles, 2018, p. 217). *Exploratory environments* enable students active discovery and exploration of MAS concepts (Çalik et al., 2014; Li & Ma, 2010; Thurm & Barzel, 2022). There are also *assessment technologies,* which provide "*review, quick in-the-moment assessment, or formative/summative assessment*" (McCulloch et al., 2018, p. 33), technologies that enable *student communication and collaboration* (Alabdulaziz, 2021; Hoyles, 2018; Li & Ma, 2010; McCulloch et al., 2018), technologies that *support reflection* (Thurm & Barzel, 2021), and *tools that connect school mathematics and learners' agendas and culture* (Hoyles, 2018).

This research focuses on three didactic aspects that form a unique combination not previously explored in studies of similar interest but that, according to the authors' experience, represent the most common teaching practices in the classroom: PIA. Our experience also indicates that these practices vary in the extent and complexity of ICT usage and, therefore, each should be examined separately.

ICT for presenting information and visual aids

Many teachers use multimedia presentations for presenting and explaining new material. These include digital games, concept maps, eBooks, and multimedia presentations (Karatza, 2019). Yao and Zhao (2022) noted that out of 1083 Chinese mathematics teachers, more than 70% reported that they use courseware and nearly 60% reported using an interactive whiteboard in their classes on a weekly–or even daily–basis. The authors term this "teacher-centered technology usage" and stressed that they were mainly for presenting information and increasing student motivation. The teachers also reported using mini-lesson videos, dynamic math software, and interactive math applets in their classes, although technologies like GeoGebra, Geometer's Sketchpad, etc. were less common (Yao & Zhao, 2022).

In a study conducted in Germany, Thurm and Barzel (2022) explored the relationships between teachers' use of multiple technological representations and their beliefs about teaching with technology, self-efficacy, and epistemology. They found that using multiple representations in class is largely independent of constructivist orientation and other aspects. Thurm and Barzel (2022) suggested that

> … supporting multiple representations with technology fits more easily into a large variety of classroom routines and does not necessarily require changes along multiple dimensions of teacher beliefs and practice compared to more disruptive practices like discovery learning or individual learning. Thus, it does not necessarily require much additional time or self-efficacy as teacher routines are disturbed less (p. 57).

ICT for inquiry

Yao and Zhao (2022) found that only one third of participating teachers used technology for inquiry-based mathematics activities that used search engines and other tools. Alabdulaziz (2021) found that only 10% of teachers used technology for inquiry. Computer algebra systems mentioned in this regard include Mathematica, Maple, MuPAD, and MathCAD. Many other studies in MAS education have pointed to the advantages of inquiry with dynamic software, in particular the use of GeoGebra (Olsher & Lavie, 2023; Segal et al., 2016; Yang et al., 2023).

Yao and Zhao (2022) found a correlation between technology use and teachers'

> "productive beliefs on students (e.g., students' disposition factors such as motivations, attitudes, social relationships, and perseverance can be improved by cultivation) and self-efficacy (e.g., each mathematics teacher has his or her own teaching style)" (p. 13).

However, it is worth noting that other studies suggest that using technology for discovery learning is challenging for teachers and its use is closely related to teachers' constructivist approach to teaching with technology, beliefs, and self-efficacy (Thurm & Barzel, 2022). Teachers also need to possess deep content knowledge and incorporate multiple representations and visual aids into various instructional methods (Kapici & Akcay, 2019).

ICT for assessment

McCulloch et al. (2018) identified a variety of ICT that were frequently used by teachers for students' assessment: Kahoot!, Socrative, Plickers, Quizlet, Mastery Connect, GradPoint, Kudo, and GradeCam. The teachers mentioned various advantages of ICT in this context, such as increased engagement, motivating students that tend not to participate, immediate feedback, and creating opportunities to see and fix mistakes during the lesson. Regarding the advantages of using a formative assessment platform based on GeoGebra, Olsher and Lavie (2023) stressed the power of immediate feedback, the ability to define characteristics for indicating student understanding and filter student answers based on these characteristics, and stimulating discussion in the class. Additional technology tools mentioned in previous studies that were used by teachers and students and that have the potential to enhance the self- and peer-assessment process and promote students' learning are e-portfolios, gamification apps, mobile devices, and WhatsApp discussion forums (Kalogiannakis et al., 2021; Segal & Biton, 2022; Torres-Madroñero et al., 2020; Zhan et al., 2023). Karatza (2019) reported on how multimedia presentations can be used for assessing students. However, in their study, Yao and Zhao (2022) found that less than a third of the participants used search engines and other ICT to analyze learning and assess students.

TPACK Framework for Teachers' Knowledge

As noted above, ICT is used for presenting information and visual aids much more extensively than for inquiry and assessment. Researchers believe that this may be related to teachers' beliefs and knowledge about technologies (e.g., Thurm & Barzel, 2022; Yao & Zhao, 2022), implying that "*some technologies align well with teacher-centered pedagogies while others provoke learner-centered pedagogies*" (Yao & Zhao, 2022, p. 3). It seems to be tightly associated with the teachers' knowledge of content, pedagogical methods, and didactical implementation of technology (Comi et al., 2017; Drijvers, 2018; Jankvist et al., 2019; Vries et al., 2018).

In this article, we build on the well-known TPACK framework that identifies the three types of knowledge (and combinations thereof) that teachers need for successful ICT integration (Koehler & Mishra, 2008; Mishra & Koehler, 2006). The TPACK model is an extension of Shulman's (1987) pedagogical and content knowledge (PCK) model, which describes the knowledge base that teachers need to develop. The addition of the technology component to Shulman's (1987) PCK model results in a total of seven knowledge categories. In addition to the original three–

(1) pedagogical knowledge (learning and teaching methods),

(2) content knowledge (the subject of study in the disciplinary field), and

(3) pedagogical content knowledge (appropriate, content-specific teaching methods)–

four more are added:

(4) technological knowledge (how to operate digital equipment and use software),

(5) technological pedagogical knowledge (how technology can be used to promote learning goals),

(6) technological content knowledge (how technology can be used to represent central or complex ideas and enrich teaching), and

(7) TPACK (how to use technology and pedagogy to promote content-specific learning goals).

The TPACK model stands out due to its distinctive approach, as it not only considers the three distinct elements of pedagogy, content, and technology, but also emphasizes the interconnectedness among them (Matherson et al., 2014). This unique feature allows the TPACK model to provide valuable insight into how to effectively integrate ICT to improve the curriculum rather than simply adding it as an addition to the lesson. Previous studies suggest the importance of the model and its connection to teachers' tendencies toward integrating technologies into their instruction (e.g., Shin, 2021). Nevertheless, Willermark (2018) in his review of 107 empirical studies published from 2011 to 2016, found that only 15.9% of subject-specific studies explored TPACK in science and only 6.5% in mathematics. This underscores the importance of research in these areas.

Teachers' Self-Reported TPACK, Use of ICT, and More

Previous research suggests a connection between a teacher's perception of their own TPACK and their propensity to incorporate novel technologies into their teaching (e.g., Harris et al., 2009; Joo et al., 2018; Schmid et al., 2021; Shin, 2021).

Some studies have emphasized the importance of the "T" component in TPACK. For example, Rakes et al. (2022), used both the TPACK and the mathematics classroom observation protocol for practices (MCOP2) frameworks to examine how 17 secondary school mathematics teacher candidates implemented technology into their classrooms in online, hybrid, and face-to-face classes during COVID-19. Their focus was on changes in student engagement (a shift to active engagement, leadership, and collaboration from the traditional, passive role) and teacher facilitation (how the teacher structures a lesson, guides the problem-solving process, and leads classroom discourse). Even though both the MCOP2 and TPACK rubrics focused on conceptual understanding and active learning, the results showed no significant correlations between the two: the analysis showed significant growth in MCOP2 but not in TPACK scores. The authors pointed out that the "T" in TPACK is an important, unique type of knowledge that does not automatically develop along with PCK, and it requires explicit emphasis on how mathematics teachers should prepare their lessons. This claim was confirmed in other studies (e.g., Marbán & Sintema, 2021; Schmid et al., 2021) that investigated pre-service teachers' TPACK and found that pre-service primary teachers generally have more PK and CK than TK. In another study, Rodríguez-Muñiz et al. (2021) investigated secondary school mathematics teachers' TPACK as demonstrated through their teaching practices during the COVID-19 pandemic. Their results suggest that teachers generally perceived their TPACK to be average and pointed out that more than half of the teachers possessed (at least some) knowledge about remote teaching and communication strategies and tools. They noted that the majority of teachers used two to four platforms simultaneously (mainly e-mail, online chats, video calling, and file storage platforms), and about 14% needed to familiarize themselves with more than three different software applications, the most popular being video editing apps and quizzes. More than 50% of participants stated that they had personally developed more than half of the materials they used.

Regarding the relation of self-perceived TPACK level with the variables of gender, teaching experience, and level of school, Ozudogru and Ozudogru (2019) developed and validated a TPACK scale for investigating these parameters in a study of Turkish mathematics teachers. The results indicated that male teachers perceived their TK significantly higher than female teachers, contrary to the findings of other researchers (Bakar et al., 2020; Schmid et al., 2021), who did not find a significant difference in teachers' TPACK according to gender. No significant correlations were found between TPACK level and level of school (Ozudogru & Ozudogru, 2019), age (Schmid et al. 2021), or teaching experience (Bakar et al., 2020; Ozudogru & Ozudogru, 2019).

Study Questions

The purpose of the current study is to investigate MAS teachers' perception of ICT integration for three distinct pedagogical purposes: PIA. Additionally, it examines teachers' self-reported TPACK and the relationship between the TPACK components and the use of ICT.

In this study, we focus on the following four questions:

1. What ICT tools do MAS teachers use for PIA and to what extent?
2. How do the characteristics of MAS teachers who use ICT to a small extent compare with those who use it to a large extent?
3. How do MAS teachers perceive their TPACK components?
4. Is there any correlation between teachers' self-reported TPACK and its components and the frequency of their use of ICT for PIA when teaching MAS? If so, what are they and are their characteristics?

MATERIALS AND METHODS

This was a quantitative study based on an online survey (questionnaire) conducted among MAS teachers. A non-probability sampling method was used. Two methods were used to collect the responses:

1. **Random sampling (availability sampling):** It employed through MAS teacher social networks and via email.
2. **Snowball:** Respondents were asked to further distribute the questionnaire among other math and science teachers.

Participants

The study population included teachers in both mathematics and the sciences, since the use of ICT in these subjects is for similar purposes (PIA) and pose similar challenges, as noted in the literature review. Of the 97 teachers who responded to a digital questionnaire, 91 agreed to take part in the study. Their demographics are summarized in **Table 1**.

Research Tool

As mentioned, this paper deals with one part of a broader study that utilized a three-part questionnaire to quantitatively assess participants'

(1) self-perceived TPACK,

(2) their attitudes towards integrating ICT into their teaching with respect to PIA, and

(3) how this correlated with their emotions.

The questionnaire was adapted from Koehler et al. (2013) and from the PANAS (positive and negative emotions) questionnaire (Watson et al., 1988). Since this article deals only with the first two aspects (knowledge and attitudes), the parts of the questionnaire dealing with emotions have been excluded from this report.

Part 1 of the questionnaire collected socio-demographic information. Part 2 and part 3 used Likert-type statements ranked on a scale from 1 (disagree/not at all) to 5 (strongly agree/very often). Part 2 assessed participants' attitudes toward integrating computerized technologies into teaching and assessment, and part 3 was divided into three subsections that focused on the extent they use ICT for PIA (9, 8, and 6 items, respectively).

The questionnaire was validated by two experts in mathematics education, two in science education, and

Table 1. Demographics of participants

Feature	Details	Average
Gender	83.5% female	45.65 & SD = 11.10
Ages	23 to 75 years	
Education	BA/BSc (17.6%), MA/MSc (70.3%), & PhD (12.1%)	
Subject taught	Mathematics (69.2%), sciences (6.6%), math and science (16.5%), & not specified (7.7%)	
Seniority	From one to 40 years	15.55 & SD = 11.11
Grades taught	Grades 1-6 (51.6%) & middle school, secondary school and/or college (48.4%)	
Participation in PD programs/ courses about integrating ICT into teaching/learning/assessment over the past five years	Not at all (7.7%), one-to-four (67.0%), & five or more (25.3%)	≈ 3 & M = 2.93

one in research methods and assessment in education. They discussed each item and, if necessary, changes were implemented until at least 80% agreement was reached. The scales' reliability was calculated using Cronbach's alpha coefficient (α) and was found to be high (ranging from .783 to .920).

Data Analysis

Variable analysis was conducted using means and standard deviations for the continuous variables. Correlations between teachers' perceptions of their TPACK components and their attitudes towards integrating ICT into their teaching in mathematics/science teaching were calculated using Pearson correlation coefficients (r).

In addition, for the purpose of processing the data, a variable called "degree of integration of computer technologies in mathematics/science teaching" was developed, which was calculated as the total rankings of all 23 items in the questionnaire (possible range of scores: 23-115). On the basis of this variable, respondents were divided into three groups depending on the degree of ICT integration they exhibited: 27.5% of respondents scored low (23-46), 46.9% scored medium (47-68), and 25.6% scored high (69-115).

RESULTS

The results, divided according to the research questions, are presented below.

Computerized Technologies That MAS Teachers Incorporate Into Teaching

A review of **Table 2**, **Table 3**, and **Table 4**, which detail the types of tools used in each area in order of use, reveals that MAS teachers make moderate use of ICT for presenting information and visual aids (**Table 2**) and for assessment (**Table 3**) and only limited use for inquiry and research (**Table 4**).

Comparison of Characteristics of MAS Teachers and Degree of ICT Use

Age

The lowest degree of integration was found among those over the age of 45 (age: mean [M] = 50.3, standard deviation [SD] = 10.5) compared to those aged 43-45 ($F_{(2, 88)} = 3.38$, $p = .038$).

Table 2. Degree of use of technological tools in the classroom for PIA (M and SD)

	M	SD
To what extent do you use any of the following to present information and as visual aids in the classroom?	2.81	0.90
Interactive presentation/presentation	3.41	1.28
Video/image/animation	3.38	1.20
Computerized environment (CET, Snunit, Yisumatica, etc.[1])	3.23	1.29
eBook	3.16	1.34
3D model	2.47	1.30
Mind Map/flowchart	2.41	1.19
Other tools (explain)	2.36	1.51
GeoGebra	2.27	1.48
Excel	2.12	1.12

Note. Range: 1-5 (5 = used very often)

[1] Hebrew–Language apps for teaching math and science.

Table 3. Degree of use of technological tools in the classroom for assessment (M and SD)

	M	SD
To what extent do you use any of the following digital tools in the classroom for assessment?	2.62	0.77
Digital practice	3.49	1.18
Digital game	3.21	1.20
Interactive video	2.96	1.23
Digital test	2.63	1.23
Survey/digital questionnaire	2.55	1.28
Digital output production by the learner	2.46	1.19
Mind Map	2.01	1.10
Other tool	1.67	1.21

Note. Range: 1-5 (5 = used very often)

Table 4. Degree of use of technological tools in the classroom for inquiry and research (M and SD)

	M	SD
To what extent do you use any of the following digital tools in the classroom for inquiry?	2.25	0.89
Widgets	3.00	1.32
Collaborative tools (document, forum, and social network)	2.78	1.40
GeoGebra	2.12	1.42
Virtual/computerized labs	2.08	1.20
Excel	1.97	1.19
Other tools	1.57	1.12

Note. Range: 1-5 (5 = used very often)

Professional development

The lowest degree of integration was found among teachers who had participated in fewer courses (M = 2.40, SD = 1.55) compared to teachers who had participated in more courses (medium integration level: M = 2.85, SD = 1.62, high integration level: M = 3.60, SD = 1.63) $F_{(2, 88)} = 3.58$, p = .032.

TPACK score

The lowest degree of integration was found among teachers with a medium TPACK score (M = 3.63, SD = 0.64) compared to teachers with a high TPACK score (medium integration level: M = 4.03, SD = 0.45, high integration level: M = 4.49, SD = 0.47; $F_{(2, 88)} = 17.89$, p < .000).

Gender

A correlation was found between gender and degree of integration. Among 60% of men, the degree of integration is low, while among women the level of integration is medium (48.7%) or high (30.3%) ($\chi^2 = 8.64$, p = .013).

Grade taught

A correlation was found between grade level(s) taught and degree of integration of ICT. For teachers who taught grade 4-garde 6, 57.4% showed a medium level of integration and 27.7% showed a high level. With respect to other teachers, 31.8% showed a medium level, and 40.9% low ($\chi^2 = 9.15$, p = .010). With respect to middle school teachers, 37.0% showed a low level of integration and 40.7% showed a high level. Among the other teachers, the level of integration is mainly moderate (54.7%) ($\chi^2 = 8.58$, p = .014).

Other variables

No significant correlations were found between TPACK and the degree of integration of ICT and the district in which the teacher teaches (North, Central, South), field of knowledge, level of degree (bachelor's, master's and doctoral), teaching in college, teaching in high school, or teaching in grade 1-grade 3.

MAS Teachers Perceptions of Their TPACK Components

Table 5 shows how teachers perceive their TPACK. Overall, they consider it high, including their CK and PK (M = 4.05, SD = .60). However, note that when the technological component is added (e.g. TCK and TPK), there is a certain decrease (M ≤ 4.0) in their feelings of capability. Note, too, that a high proportion of MAS teachers were confident of their MAS thinking, but least confident with being up-to-date with new technological tools.

Correlation Between Self-Reported TPACK and Use of ICT

Table 6 shows the correlations between teachers' average perceptions of their TPACK and their degree of integration of ICT into teaching in the three areas under study. The results are significant and moderately positive. In other words, the higher the teachers' perception of their TPACK, the more they reported using ICT.

Table 5. Means and standard deviations of teachers' perception of knowledge components in relation to the use of technological tools in teaching according to 14 TPACK components TPACK

		M	SD
Mean TPACK		4.05	0.60
CK	I have mathematical/scientific thinking.	4.47	0.77
PK	I know how to navigate a class.	4.35	0.67
CK	I have sufficient content knowledge in math/science.	4.33	0.80
PK	I know how to use a wide variety of approaches to teaching in the classroom.	4.14	0.75
TK	I can easily learn how to use computerized technological tools.	4.13	0.95
PCK	I know how to choose effective teaching approaches to foster mathematical/scientific thinking.	4.09	0.75
TK	I have the skills necessary for the use of computer technologies.	4.08	0.87
PK	I know how to evaluate student learning in a variety of ways.	4.07	0.80
TPK	I know how to choose computerized technologies that promote the lesson content.	4.00	0.95
TPK	I know how to adapt the use of computerized technologies to different teaching activities.	3.91	0.88
TCK	I know how to use computerized technologies to understand and apply mathematical/scientific topics.	3.85	0.88
TPK	I know how to choose computerized technologies that promote teaching approaches in the classroom.	3.81	0.89
TK	I keep up to date with new technological tools.	3.77	0.99
TPACK	I know how to teach a lesson that properly combines math/science, computer technologies and teaching approaches.	3.65	0.98

Table 6. Pearson correlations (r) between teachers' perceptions of their TPACK and the extent to which technological tools are used in math/science teaching for the three areas under study (N = 91)

Area of integration	PIA	Assessment	Inquiry
r	.40***	.50***	.53***

Note. ***p ≤ .0001

Using at least $p < .01$ to define a significant correlation between the 14 TPACK items and each of the three areas of use under study, the number of correlations ranged from using ICT for inquiry (13), for assessment (11), and for presenting information and visual aids (9), while the highest degree of use was for presenting information and visual aids and the lowest for inquiry (see **Table 2**, **Table 3**, and **Table 4**). These trends are illustrated in **Figure 1**.

Table 7 presents an analysis of the significant correlations (at least $p < .01$) between the 14 TPACK items and use of ICT tools used in each of the three categories. As can be seen, the highest percentage of correlations are for "assessment" (47% of correlations) and "inquiry" (45.7%), whereas only 14.3% correlated with its use for "presenting information and visual aids."

Within each category, the results show that for "presenting information and visual aids," "computerized environment" had the largest number (7/14) of distinct correlations with the TPACK items; in the "assessment" category, "digital practice" and "digital survey/questionnaire" had the largest numbers of significant correlations (10/14 and 9/14, respectively); and in the "inquiry" category, "collaborative tools" and "widgets" (11/14 and 10/14, respectively). Thus, it seems that the use of ICT is dependent on teachers having a broad, positive perception towards their TPACK.

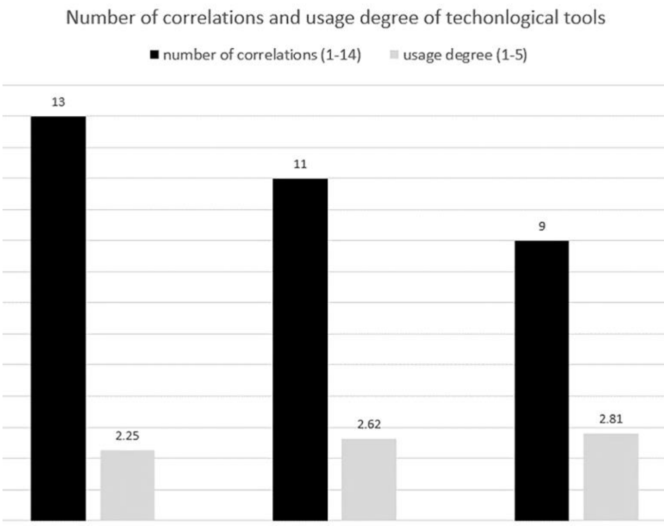

Figure 1. Degree of use of technological tools in the three areas of use in teaching compared to the number of correlations found between teachers' TPACK (Source: Authors' own elaboration)

When examining correlations between TPACK items and types of ICT used (various tools), it was found that over half (56%) of the significant correlations were connected to five statements, all of which included a TK component. These are detailed in **Table 8** along with these results in the overall average for the field of use and the five selected items. The highest percentage of correlations with these TPACK items were its use for assessment, followed by for inquiry, and finally for presentation and visual aids (60%, 53%, and 50%, respectively).

To sum up **Table 8**, it can be said that the more significant items that correlate with the teachers' self-concept of their TPACK are selecting and/or adapting ICT to promote the content of the lesson, various

Table 7. Number and percentage of significant correlations relative to TPACK and average use of technological tools for teaching in each type of use and in the five selected statements (N = 91)

TPACK–Total 14 items	Percentage of all items	Percentage of items in specific area
USE–Total 20 items (no other)	33.6% (94/280)	
Category: Presentation and visual aids (8 items)	14.3% (16/112)	
Computerized environment		50% 7/14
Category: Assessment (7 items)	47.0% (46/98)	
Digital practice		71.4% (10/14)
Category: Inquiry (5 items)	45.7% (32/70)	
Widgets		71.4% (10/14)
Collaborative tools		78.6% (11/14)

Note. This table refers to 14 TPACK items and 20 items that represent various technological tools for presenting information and visual aids, inquiry, and assessment (in other words, a total of 280 correlations were examined)

Table 8. TPACK items which are significantly correlated with use of technological tools

		Item (13) TPK	Item (12) TPK	Item (11) TPK	Item (10) TCK	Item (2) TK
Number of correlations in:	Number of correlations with five selected items	"I know how to choose computerized technologies that promote the content of the lesson"	"I know how to adapt the use of computerized technologies to different teaching activities"	"I know how to choose computerized technologies that promote teaching approaches in the classroom"	"I know how to use computerized technologies to understand and apply mathematical/ scientific topics"	"I'm up to date with new technological tools"
PIA	8 (50%) (8/16)	2	1	2	1	2
Assessment	28 (60%) (28/46)	7	7	5	5	4
Inquiry	17 (53%) (17/32)	4	2	4	3	4
Total (20 items)	53 (56%) (53/94)	13	10	11	9	10

teaching activities, to enhance teaching, to advance understanding of MAS topics, and for keeping abreast of new technological tools. The statements shown are all related to TK, TCK, or TPK (i.e., include a technological component). In other words, it seems that the technological component is important when it comes to using ICT.

DISCUSSION

This discussion explores the relationship between different aspects of TPACK competence and use of ICT, focusing on the pedagogical purposes most closely associated with TPACK components, the ICT that exhibits the strongest connection with TPACK components, and, vice versa, the key TPACK items linked to ICT usage.

Using ICT for PIA

The findings of this research indicate that MAS teachers use ICT to a moderate extent for presenting information and visual aids and for assessment, and to a low extent for inquiry. These finding are contrary to the study by Yao and Zhao (2022), who found extensive use of ICT among mathematics teachers mostly for presenting information and student motivation and also to the results of Kadıoğlu-Akbulut et al. (2023), who found that preservice science teachers had high scores in most dimensions of technology use. Our findings are interesting given that the research took place during the late stages of the COVID-19 pandemic, when teachers had accumulated significant experience in remote teaching, something that should have enhanced their use of ICT. On the other hand, this study's findings with respect to the use of ICT for inquiry and assessment corroborate those of Yao and Zhao (2022), who found that only one third of teachers used technology for those purposes.

Close examination of the ICT used by teachers revealed that the most frequently used tools agreed with the findings of other researchers. For example, for *presenting information and visual aids*, the most frequently used tools were presentations/interactive presentations, videos/pictures/animations (similar to Karatza, 2019; Yao & Zhao, 2022), computerized environments (such as GeoGebra, Desmos, and other applications), and digital textbooks. The least used tools were GeoGebra and Excel. *For assessment*, the most frequently used were digital exercises and digital games (in line with McCulloch et al., 2018) and the least used were concept maps. For *inquiry*, we noted that the most frequently used were applications and collaborative platforms (documents, forums, social networks), and least frequently were GeoGebra, virtual/computer labs, and Excel. In fact, GeoGebra and Excel require adaptation for each lesson, so this suggests that teachers prefer ICT that is readily available and does not require excessive time for adapting or preparation. Trying to explain similar findings, Yao and Zhao (2022) suggested that teachers integrate technologies that align with their existing pedagogical practices, what they describe, as noted earlier, as "teacher-centered" technology usage.

Regarding the differences in usage for the three purposes, the current findings are in line with previous studies that found ICT less used for inquiry, despite its advantages (Alabdulaziz, 2021; Olsher & Lavie, 2023; Segal et al., 2016; Yang et al., 2023; Yao and Zhao, 2022). A possible explanation is that this requires teachers to modify their beliefs, especially their productive beliefs regarding their students and their self-efficacy (see, e.g., Thurm & Barzel, 2022; Yao & Zhao, 2022), in addition to modifying their attitudes with respect to the constructivist method of teaching (Thurm & Barzel, 2022), and increasing their content knowledge (Kapici & Akcay, 2019). On the other hand, utilizing ICT for visual aid aligns with a wide range of existing teaching routines and does not demand teachers to modify their beliefs nor require a significant amount of additional effort (Thurm & Barzel, 2022).

Characteristics of Teachers Who Use ICT to a Small Extent Compared to Those Who Use It to a High Extent

This study found that ICT usage could be linked to the age of the teacher (older teachers use it less, in line with studies by Perienen, 2020; Umugiraneza et al., 2018; Yao & Zhao, 2022); teacher's participation in professional development courses (more participation resulted in a higher tendency to use ICT, in line with studies by Mueller et al., 2008 and Umugiraneza et al., 2018); and their self-perception of their TPACK (a high self-perception led to more willingness to integrate new technologies into their teaching, similar to Schmid et al., 2021; Shin, 2021). Our results showed that the lowest level of ICT integration was among teachers who had only a medium TPACK score. This may also be connected to the correlation we found between attendance in professional development courses, as such participation would tend to enhance teachers' TPACK.

Another interesting finding is the link between gender and ICT use: about 60% of males used ICT at a low extent, while about 80% of females used ICT at a moderate to high extent. This finding was surprising and contradicts that of Umugiraneza et al. (2018), who found that male teachers were more inclined to incorporate ICT into their teaching. This contradiction in results may be worthy of further study to determine if there are unique characteristics of the teacher population in Israel that lead to it.

Another characteristic examined was the grade taught. ICT integration in Grades 4-6 was relatively high compared to the other grades: in fact most (85%) of the teachers of these grades used ICT to a moderate to high extent, while most (72%) of teachers of other grade levels used ICT to a moderate or low extent. This may be explained by the fact that in grade 1-grade 3, mathematics is usually taught by general class teachers, regardless of their specific disciplinary training, whereas from grade 4 and up, math is primarily taught by teachers specializing in MAS. This is in accordance with the Israeli Ministry of Education's (2019) policy that "mathematics lessons will be taught by teachers trained in mathematics education, who consistently engage in professional development related to mathematical content and pedagogy" and thus it may be assumed that knowledge about integrating ICT into teaching was part of these teachers' training.

An interesting finding was that teacher of grade 4-grade 6 demonstrated a greater propensity for incorporating ICT than those of higher grades, a finding consistent with that of Yao and Zhao (2022). Future studies might examine the reasons for these differences.

Teacher's Self-Reported TPACK

With respect to teachers' self-reported TPACK, the majority of teachers reported a relatively high average, consistent with the findings of Marbán and Sintema (2021) and Kadıoğlu-Akbulut et al. (2023), but contrary to the findings of Rodríguez-Muñiz et al. (2021), which found that secondary mathematics teachers perceived their TPACK as average. When examined separately, our study found CK, PK, and PCK measures also to be relatively high.

As mentioned earlier, previous studies have highlighted the particular significance of the "T" component within TPACK and its significance in incorporating ICT into teaching (Marbán & Sintema, 2021; Rakes et al., 2022; Schmid et al., 2021). Upon a thorough examination of the various knowledge components, it became evident that the addition of the "technological" component led to a certain decrease in the teachers' extent of agreement with the statements that pertained to these groups of knowledge (namely, TCK, TPK, and TPACK). This corroborates what other researchers have found in studies of pre-service primary-school teachers: they tend to have more content and pedagogical knowledge than technological knowledge. The authors contend that the "T" component in TPACK is a unique type of knowledge that does not automatically develop and therefore requires explicit emphasis in mathematics teachers' courses (e.g., Marbán & Sintema, 2022; Schmid et al., 2021). Our findings of in-service teachers confirm this observation.

Also noticeable in our findings was that even though MAS teachers had a relatively high TPACK, they used ICT to a moderate-to-small extent. It thus seems reasonable to assume that other factors are involved, and, indeed, other factors have been investigated by others, including beliefs (Thurm & Barzel, 2022; Tondeur et al., 2017; Yao & Zhao, 2022), self-efficacy (Bakar et al., 2020), demographic variables (Perienen, 2020; Yao & Zhao, 2022), and more.

Correlation Between Teachers' Perceptions of Their TPACK and the Extent of Their Use of ICT for PIA

Our findings show positive, moderate, and significant correlations between the teachers' self-reported average TPACK and the extent of how they integrate ICT when teaching mathematics/science in PIA, which is in line with previous studies (e.g., Agyei & Voogt, 2012; Harris et al., 2009; Nantschev et al., 2020; Schmid et al., 2021; Shin, 2021). Moreover, a close examination of the significant correlations between each of the TPACK items and the average of the extent of use of the different tools in each of the three PIA categories (**Figure 1**) shows that the largest number of significant correlations occurred with "use of technological tools for inquiry," followed by "use of technological tools for assessment," and then "use of technological tools for presenting information and visual aids," which had the lowest number of significant correlations. Furthermore, a thorough examination of correlations between the TPACK items and the extent of use of each one of the ICT in each of the PIA categories (**Table 7**) indicates that almost half the correlations that were associated with "use of technological tools for inquiry" (45.7%) and "use of technological tools for assessment" (47%) were significant compared to "use of technological tools for presenting information and visual aids" (only 14% significant).

These results can explain the findings described above, that is, that MAS teachers use ICT to a small extent for inquiry purposes in the classroom, suggesting that when teachers use technology for inquiry they need extensive TPACK, in contrast to what they need for "Presenting information and visual aids." This finding complements the claims of Thurm and Barzel (2022), who suggested that using multiple representations in class is largely independent of constructivist orientation and does not require changing teachers' beliefs or teaching routines and practices.

Regarding the usage of different ICT in PIA categories in relation to TPACK items, we found that a computerized environment, digital practice collaborative tools, and widgets, produced a higher number of significant correlations with the TPACK items (**Table 7**). That is, the use of these tools for teaching is related to whether or not teachers have an extensive and solid perception of their TPACK. Surprisingly, as we saw above, all of these tools, except for digital survey/questionnaires, were found to be the most frequently used tools by teachers in the classrooms.

It is encouraging that, despite the finding that the overall extent of use of ICT by teachers is moderate to small, teachers do frequently use tools that are associated with extensive TPACK. From this finding, one can conclude that the teachers' ICT use is not mostly "teacher-centered" as claimed by Yao and Zhao (2022) but is related to solid and well-established TPACK. This finding also reinforces the findings of other studies that suggest that the extent of use of ICT relates not only to TPACK but to other factors, such as age (Perienen, 2020; Umugiraneza et al., 2018; Yao & Zhao, 2022), teaching experience (Inan & Lowther, 2010), technology perception (Perienen, 2020; Ritzhaupt et al., 2012), grade level (Umugiraneza et al., 2018; Yao & Zhao, 2022), mathematical topic (McCulloch et al., 2018), and more.

Upon examination of the correlations between the TPACK items and the extent of use of the ICT in the PIA categories (**Table 8**), five TPACK items that are responsible for over half of the statistically significant correlations stood out. This suggests that these may be regarded as "core" items when it comes to ICT use. Noticeably, all five relate to "technological" TPACK components. This finding provides further evidence that the technological aspect of teachers' knowledge is the one most significant aspect related to their use of ICT for PIA. This finding is consistent with previous findings (Marbán & Sintema, 2021; Rakes et al., 2022; Schmid et al., 2021) and can be transformed into practical aspects in preservice and in-service teachers training.

CONCLUSIONS: SIGNIFICANCE, PRACTICAL IMPLICATIONS, LIMITATIONS, AND SUGGESTIONS FOR FURTHER STUDY

This study shows that in order to improve teachers' ability to use ICT in MAS, it is important to strengthen the five TPACK items noted above during teacher training and to increase teachers' familiarity with available technological tools. This is especially important for the MAS disciplines, as it is important that technology become a central factor in learning and understanding MAS subjects. In addition, given that "keeping up to date with technological tools" scored the lowest of all the "core" items, teachers should be taught the importance of keeping current with newly available technological tools and giving them the skills to do so, to ensure that this becomes part of their daily routine. It is also important to place greater emphasis on the variety of opportunities for choosing ICT and how to adapt them to the lesson content. Also, deepening teachers' TPACK in the context of those technological tools that were found to be most related to TPACK is recommended to increase the chances of ICT integration. Especially important would be fostering familiarity with as many computerized environments as possible that can be used for presenting information and visual aids;

providing digital practice for assessment; and furnishing collaborative tools and widgets for inquiry. With regard to those tools that were not found to have a significant connection to TPACK, it might be worthwhile to follow up this research with a study to examine specific factors related to their use and consider how to increase their integration into teaching.

In conclusion, even though this study was conducted toward the end of the COVID-19 pandemic, during which teachers accumulated vast experience in using technology, we found that teachers did not really exploit this experience. At the same time, we found that most teachers had relatively high TPACK, and that the use of ICT was somewhat related to extensive TPACK.

In addition, it was encouraging to find that most agreed that they could easily learn how to use computerized technological tools and that they had the necessary skills to do so, indicating that there is fertile ground for the desired change. This means that teacher educators should take advantage of the opportunity created by the COVID-19 period to leverage the skills acquired in the use of ICT so as to realize the great potential it can offer for improving teaching and learning MAS.

Regarding the study's limitations, it is important to note that a self-report questionnaire is inherently limited due to social desirability bias. We therefore recommend that future studies incorporate supplementary research methods (e.g., classroom observations, interviews) to provide a more comprehensive understanding of teachers' actual use of ICT. Additionally, the sample was not random: only teachers who opted to participate completed the questionnaire; most of the respondents had a master's degree; and there were more mathematics teachers than science teachers. Future studies might examine these populations separately to facilitate a thorough investigation of ICT use within each and a more profound comprehension of how different teachers integrate ICT, thus yielding more specific suggestions for advantageous use of ICT within each educational setting.

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REFERENCES

Agyei, D. D., & Voogt, J. (2012). Developing technological pedagogical content knowledge in pre-service mathematics teachers through collaborative design. *Australasian Journal of Educational Technology, 28*(4). https://doi.org/10.14742/ajet.827

Alabdulaziz, M. S. (2021). COVID-19 and the use of digital technology in mathematics education. *Education and Information Technologies, 26*(6), 7609-7633. https://doi.org/10.1007/s10639-021-10602-3

Bakar, N. S. A., Maat, S. M., & Rosli, R. (2020). Mathematics teacher's self-efficacy of technology integration and technological pedagogical content knowledge. *Journal on Mathematics Education, 11*(2), 259-276. https://doi.org/10.22342/jme.11.2.10818.259-276

Ball, L., Drijvers, P., Ladel, S., Siller, H. S., Tabach, M., & Vale, C. (Eds.). (2018). *Uses of technology in primary and secondary mathematics education: Tools, topics and trends*. Springer. https://doi.org/10.1007/978-3-319-76575-4

Çalik, M., Ebenezer, J., Özsevgeç, T., Küçük, Z., & Artun, H. (2014). Improving science student teachers' self perceptions of fluency with innovative technologies and scientific inquiry abilities. *Journal of Science Education and Technology, 24*(4), 448-460. https://doi.org/10.1007/s10956-014-9529-1

Chien, S. P., & Wu, H. K. (2020). Examining influences of science teachers' practices and beliefs about technology-based assessment on students' performances: A hierarchical linear modeling approach. *Computers & Education, 157*. https://doi.org/10.1016/j.compedu.2020.103986

Clarke, I., Flaherty, T. B., & Yankey, M. (2006). Teaching the visual learner: The use of visual summaries in marketing education. *Journal of Marketing Education, 28*(3), 218-226. https://doi.org/10.1177/0273475306291466

Comi, S. L., Argentin, G., Gui, M., Origo, F., & Pagani, L. (2017). Is it the way they use it? Teachers, ICT and student achievement. *Economics of Education Review, 56*, 24-39. https://doi.org/10.1016/j.econedurev.2016.11.007

Dogan, S., Dogan, N. A., & Celik, I. (2021). Teachers' skills to integrate technology in education: Two path models explaining instructional and application software use. *Education and Information Technologies, 26*, 1311-1332. https://doi.org/10.1007/s10639-020-10310-4

Drijvers, P. (2018). Tools and taxonomies: A response to Hoyles. *Research in Mathematics Education, 20*(3), 229-235. https://doi.org/10.1080/14794802.2018.1522269

Drijvers, P. (2019). Head in the clouds, feet on the ground–A realistic view on using digital tools in mathematics education. In A. Büchter, M. Glade, R. Herold-Blasius, M. Klinger, F. Schacht, & P. Scherer (Eds.), *Vielfältige Zugänge zum Mathematikunterricht* (pp. 163-176). Springer. https://doi.org/10.1007/978-3-658-24292-3_12

Drijvers, P. H. M., Ball, L., Barzel, B., Heid, M. K., Cao, Y., & Maschietto, M. (2016). *Uses of technology in lower secondary mathematics education: A concise topical survey*. Springer. https://doi.org/10.1007/978-3-319-33666-4

Fuchsova, M., & Korenova, L. (2019). Visualisation in basic science and engineering education of future primary school teachers in human biology education using augmented reality. *European Journal of Contemporary Education, 8*(1), 92-102. https://doi.org/10.13187/ejced.2019.1.92

Harris, J., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education, 41*(3), 393-416. https://doi.org/10.1080/15391523.2009.10782536

Hegedus, S. J., & Roschelle, J. (Eds.) (2013). *The SimCalc vision and contributions: Democratizing access to important mathematics.* Springer. https://doi.org/10.1007/978-94-007-5696-0

Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., & Reiss, K. M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. *Computers & Education, 153*, Article 103897. https://doi.org/10.1016/j.compedu.2020.103897

Hoyles, C. (2018). Transforming the mathematical practices of learners and teachers through digital technology. *Research in Mathematics Education, 20*(3), 209-228. https://doi.org/10.1080/14794802.2018.1484799

Hoyles, C., Noss, R., Vahey, P., & Roschelle, J. (2013). Cornerstone mathematics: Designing digital technology for teacher adaptation and scaling. *ZDM–Mathematics Education, 45*(7), 1057-1070. https://doi.org/10.1007/s11858-013-0540-4

Inan, F., & Lowther, D. (2010). Factors affecting technology integration in K-12 classrooms: A path model. *Educational Technology Research and Development, 58*, 137-154. https://doi.org/10.1007/s11423-009-9132-y

Jankvist, U. T., Misfeldt, M., & Aguilar, M. S. (2019). What happens when CAS procedures are objectified? The case of "solve" and "desolve". *Educational Studies in Mathematics, 101*(1), 67-81. https://doi.org/10.1007/s10649-019-09888-5

Joo, Y. J., Park, S., & Lim, E. (2018). Factors influencing preservice teachers' intention to use technology: TPACK, teacher self-efficacy, and technology acceptance model. *Educational Technology & Society, 21*(3), 48-59. http://www.jstor.org/stable/26458506

Kadıoğlu-Akbulut, C., Cetin-Dindar, A., Acar-Şeşen, B., & Küçük, S. (2023). Predicting preservice science teachers' TPACK through ICT usage. *Education and Information Technologies, 28*, 11269-11289. https://doi.org/10.1007/s10639-023-11657-0

Kalogiannakis, M., Papadakis, S., & Zourmpakis, A. I. (2021). Gamification in science education. A systematic review of the literature. *Education Sciences, 11*(1), Article 22. https://doi.org/10.3390/educsci11010022

Kapici, H. O., & Akcay, H. (2019). Cognitive theories of learning on virtual science laboratories. In M. Shelley, & S. Ahmet Kiray (Eds.), *Education research highlights in mathematics, science and technology 2019* (pp. 107-126). ISRES Publishing.

Karatza, Z. (2019). Information and communication technology (ICT) as a tool of differentiated instruction: An informative intervention and a comparative study on educators' views and extent of ICT use. *International Journal of Information and Education Technology, 9*(1), 8-15. https://doi.org/10.18178/ijiet.2019.9.1.1165

Koehler, M. J., & Mishra, P. (2008). Introducing TPCK. In AACTE Committee on Innovation and Technology (Ed.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 3-29). Lawrence Erlbaum Associates. https://doi.org/10.4324/9781315759630

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education, 193*(3), 13-19. https://doi.org/10.1177/002205741319300303

Körtesi, P., Simonka, Z., Szabo, Z. K., Guncaga, J., & Neag, R. (2022). Challenging examples of the wise use of computer tools for the sustainability of knowledge and developing active and innovative methods in STEAM and mathematics education. *Sustainability, 14*(20), Article 12991. https://doi.org/10.3390/su142012991

Li, Q., & Ma, X. (2010). A meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review, 22*(3), 215-243. https://doi.org/10.1007/s10648-010-9125-8

Marbán, J. M., & Sintema, E. J. (2021). Pre-service teachers' TPACK and attitudes toward integration of ICT in mathematics teaching. *International Journal for Technology in Mathematics Education, 28*(1), 37-46. https://doi.org/10.1564/tme_v28.1.03

Matherson, L. H., Wilson, E. K., & Wright, V. H. (2014). Need TPACK? Embrace sustained professional development. *Teaching Performance, 81*, 45–52.

McCulloch, A. W., Hollebrands, K., Lee, H., Harrison, T., & Mutlu, A. (2018). Factors that influence secondary mathematics teachers' integration of technology in mathematics lessons. *Computers & Education, 123*, 26-40. https://doi.org/10.1016/j.compedu.2018.04.008

Ministry of Education. (2019). Directive No. 0238: Mathematics education in elementary and pre-primary education. *Ministry of Education*. https://apps.education.gov.il/mankal/Horaa.aspx?siduri=293#_Toc256000043

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mueller, J., Wood, E., Willoughby, T., Ross, C., & Specht, J. (2008). Identifying discriminating variables between teachers who fully integrate computers and teachers with limited integration. *Computers & Education, 51*(4), 1523-1537. https://doi.org/10.1016/j.compedu.2008.02.003

Nantschev, R., Feuerstein, E., González, R. T., Alonso, I. G., Hackl, W. O., Petridis, K., Triantafyllou, E., & Ammenwerth, E. (2020). Teaching approaches and educational technologies in teaching mathematics in higher education. *Education Sciences, 10*(12), Article 354. https://doi.org/10.3390/educsci10120354

National Research Council. (2013). *Next generation science standards: For states, by states*. The National Academies Press. https://doi.org/10.17226/18290

NCTM. (2008). The role of technology in the teaching and learning of mathematics. *National Council of Teachers of Mathematics*. http://www.nctm.org

Ocak, C., & Baran, E. (2019). Observing the indicators of technological pedagogical content knowledge in science classrooms: Video-based research. *Journal of Research on Technology in Education, 51*(1), 43-62. https://doi.org/10.1080/15391523.2018.1550627

Olsher, S., & Lavie, I. (2023). Design of tasks for assessment of generalization abilities of preservice teachers of elementary school mathematics. *International Journal of Mathematical Education in Science and Technology, 54*(5), 706-724. https://doi.org/10.1080/0020739X.2021.1962999

Ozudogru, M., & Ozudogru, F. (2019). Technological pedagogical content knowledge of mathematics teachers and the effect of demographic variables. *Contemporary Educational Technology, 10*(1), 1-24. https://doi.org/10.30935/cet.512515

Perienen, A. (2020). Frameworks for ICT integration in mathematics education: A teacher's perspective. *Eurasia Journal of Mathematics, Science and Technology Education, 16*(6), Article em1845. https://doi.org/10.29333/ejmste/7803

Polly, D. (2014). Elementary school teachers' use of technology during mathematics teaching. *Computers in the Schools, 31*(4), 271-292. https://doi.org/10.1080/07380569.2014.969079

Rakes, C. R., Stites, M. L., Ronau, R. N., Bush, S. B., Fisher, M. H., Safi, F., Desai, S., Schmidt, A., Andreasen, J. B., Saderholm, J., Amick, L., Mohr-Schroeder, M. J., & Viera, J. (2022). Teaching mathematics with technology: TPACK and effective teaching practices. *Education Sciences, 12*(2), Article 133. https://doi.org/10.3390/educsci12020133

Ritzhaupt, A. D., Dawson, K., & Cavanaugh, C. (2012). An investigation of factors influencing student use of technology in K-12 classrooms using path analysis. *Journal of Educational Computing Research, 46*(3), 229-254. https://doi.org/10.2190/EC.46.3.b

Rodríguez-Muñiz, L. J., Burón, D., Aguilar-González, Á., & Muñiz-Rodríguez, L. (2021). Secondary mathematics teachers' perception of their readiness for emergency remote teaching during the COVID-19 pandemic: A case study. *Education Sciences, 11*(5), Article 228. https://doi.org/10.3390/educsci11050228

Schmid, M., Brianza, E., & Petko, D. (2021). Self-reported technological pedagogical content knowledge (TPACK) of pre-service teachers in relation to digital technology use in lesson plans. *Computers in Human Behavior, 115,* Article 106586. https://doi.org/10.1016/j.chb.2020.106586

Segal, R., Biton, Y. (2024). Teaching and learning high-school mathematics via WhatsApp: teachers' perspectives. *Learning Environment Research*, 1-29. https://doi.org/10.1007/s10984-024-09508-x

Segal, R., Stupel, M., & Oxman, V. (2016). Dynamic investigation of loci with surprising outcomes and their mathematical explanations. *International Journal of Mathematical Education in Science and Technology, 47*(3), 443-462. https://doi.org/10.1080/0020739X.2015.1075613

Sever, S., Oguz-Unver, A., & Yurumezoglu, K. (2013). The effective presentation of inquiry-based classroom experiments using teaching strategies that employ video and demonstration methods. *Australasian Journal of Educational Technology, 29*(3). https://doi.org/10.14742/ajet.229

Shin, D. (2021). Teaching mathematics integrating intelligent tutoring systems: Investigating prospective teachers' concerns and TPACK. *International Journal of Science and Mathematics Education, 20*, 1659-1676. https://doi.org/10.1007/s10763-021-10221-x

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Thurm, D., & Barzel, B. (2022). Teaching mathematics with technology: A multidimensional analysis of teacher beliefs. *Educational Studies in Mathematics, 109*(1), 41-63. https://doi.org/10.1007/s10649-021-10072-x

Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development, 65*(3), 555-575. https://doi.org/10.1007/s11423-016-9481-2

Torres-Madroñero, E. M., Torres-Madroñero, M. C., & Ruiz Botero, L. D. (2020). Challenges and possibilities of ICT-mediated assessment in virtual teaching and learning processes. *Future Internet, 12*(12), Article 232. https://doi.org/10.3390/fi12120232

Umugiraneza, O., Bansilal, S., & North, D. (2018). Exploring teachers' use of technology in teaching and learning mathematics in KwaZulu-Natal schools. *Pythagoras, 39*(1). https://doi.org/10.4102/pythagoras.v39i1.342

Vries, P., Klaassen, R., Ceulemans, D., & Ioannides, M. (2018). *Emerging technologies in engineering education: Do we need them and can we make them work?* Centre for Engineering Education. https://doi.org/10.13140/RG.2.2.16595.84008

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology, 54*(6), Article 1063. https://doi.org/10.1037/0022-3514.54.6.1063

Willermark, S. (2018). Technological pedagogical and content knowledge: A review of empirical studies published from 2011 to 2016. *Journal of Educational Computing Research, 56*(3), 315-343. https://doi.org/10.1177/0735633117713114

Yang, K. L., Cheng, Y. H., Wang, T. Y., & Chen, J. C. (2023). Preservice mathematics teachers' reasoning about their instructional design for using technology to teach mathematics. *Asia-Pacific Journal of Teacher Education, 51*(3), 248-265. https://doi.org/10.1080/1359866X.2023.2198116

Yao, X., & Zhao, J. (2022). Chinese mathematics teachers' use of digital technologies for instruction: A survey study. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(8), Article em2135. https://doi.org/10.29333/ejmste/12209

Zhan, Y., Yan, Z., Hong Wan, Z., Wang, X., Zeng, Y., Yang, M., & Yang, L. (2023). Effect of online peer assessment on higher-order thinking: A meta-analysis. *British Journal of Educational Technology, 54*(4), 817-8355. https://doi.org/10.1111/bjet.13310