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Changes in the attitudes of mathematics and science teachers toward the integration and use of computerized technological tools as a result of the COVID-19 pandemic

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Abstract

This quantitative retrospective study examines a non-probable convenience sample of 104 in-service mathematics and science teachers with the aim to understand their changes in attitudes toward the integration and use of information and communications technology (ICT) as a result of the COVID-19 pandemic. Data included a self-report questionnaire. The results indicate an increase in teachers' knowledge regarding the e-learning environments available at their schools. The teachers revealed that before the pandemic, they mostly used computer tools to support struggling students or carry out basic calculations. However, during, because they had to plan distance learning environments, they introduced adaptive pedagogical use of ICT tools for all their students. The findings reveal that most teachers experienced difficulties emanating from lack of preparation time, technological knowledge, and/or technical conditions, thus suggesting that policymakers must decide how to provide adequate knowledge and technical support to allow teachers to successfully integrate computerized technologies into their teaching.

Keywords: teachers' attitudes, technology integration, ICT tools, TPACK

INTRODUCTION

The COVID-19 pandemic that descended on the world in early 2020 forced a rapid transition to use of digital media and wholly online teaching environments, termed emergency remote teaching (ERT) (Green et al., 2020). This differs from planned online information and communications technology (ICT) learning, which is prearranged and carefully designed. In case of ERT, teachers were suddenly forced to move from a face-to-face modality to an online one without any prior preparation (Bozkurt et al., 2020; Hodges et al., 2020; Ng, 2021). As a result, teachers were forced to adapt their instruction to cope with technological innovations and platforms with which they had no familiarity.

Since teachers' attitudes hold the key to successful educational innovation, teachers' views regarding any aspect of their profession that might impact their behavior are important (Lucas et al., 2021; OECD, 2019a; Scherer et al., 2018). Research on in-service teachers' attitudes toward ICT is longstanding (Eickelmann & Vennermann, 2017) and has shown that positive attitudes towards the use of digital media in class enable teachers to adapt to new educational technologies, resources, and options (Krause et al., 2017). Successful adaptation of technology in the school system is influenced by many factors, including teachers' awareness of the available technological environments, school resources, school culture, and the technological knowledge and experience that teachers and students have (Bingimlas, 2009; Lim et al., 2013). These factors influence how amenable teachers are to integrating ICT into their teaching. Nevertheless, the literature (Urezm et al., 2018) indicates that despite the advantages provided by ICT teachers' use of ICT–certainly prior to the COVID-19 pandemic–was not widespread.

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Contribution to the literature

- The research focuses specifically on mathematics and science teachers' attitudes toward the integration of various technologies in teaching.
- The research underscores that teachers' TPACK that may be adequate for face-to-face teaching, requires expansion and adaptation for distance teaching.
- The research highlights that teachers generally regard the purpose of computer technology tools in teaching to be primarily to create collaborative learning environments. The study proposes suggestions for deepening and expanding pre- and in-service mathematics and science teachers' TPK and TK.

As mentioned earlier, the COVID-19 pandemic forced teachers to change their instruction methods so as to integrate and use new technological tools in their teaching. This led us to seek to examine–post pandemic–in-service teachers' attitudes towards the integration and use of ICT tools in their lessons as a result of the pandemic. We thus conducted a study based on the following research questions:

(1) Has there been a change in mathematics and science teachers' technological knowledge (TK) regarding ICT environments and their integration into teaching since the outbreak of the COVID-19 pandemic?

(2) Have mathematics and science teachers' attitudes about the purpose of ICT tools changed since the outbreak of the COVID-19 pandemic?

(3) What difficulties did mathematics and science teachers experience regarding integrating ICT tools into teaching before the outbreak of the COVID-19 and what are the difficulties they have experienced since?

LITERATURE REVIEW

Integration, Uses, & Barriers of ICT in Teaching & Learning

The last decades have seen an increase in the assimilation of ICT in schools worldwide. Studies show that ICT grants students new learning skills and opportunities to search and analyze information, communicate with their colleagues, and solve problems. It also bestows competencies needed for the 21st century (Lin et al., 2013; National Research Council, 2013; Niess & Gillow-Wiles, 2017). Teachers play a key role in preparing students for their future as citizens, including informed exposure to technology and its uses (Chand et al., 2020).

The literature describes various models in the context of teacher's knowledge with respect to integrating technology into teaching processes. One important model is TPACK (technological, pedagogical, and content knowledge) model (Koehler & Mishra, 2009, based on Shulman, 1986), which is an amalgamation of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). TK is knowledge about the various technologies available for teaching in the classroom environment and became of paramount importance during ERT (Green et al., 2020; Marissa & Allahji, 2021).

TPACK implies that all three bodies of knowledge intersect at various levels of complexity (Klemer et al., 2020a, 2020b; Segal et al., 2021). The model has become a useful framework to understand the goals involved in integrating technology into teacher education, as well as mapping teacher knowledge and developing research tools, because it encompasses the knowledge teachers require to effectively integrate technology during their teaching (Agyei & Voogt, 2012; Meadows & Caniglia, 2018; Nantschev et al., 2020; Polly & Orrill, 2012; Schmidt et al., 2009). The model's complexity is reflected in the common components of basic knowledge. For example, TCK−technological content knowledge−is knowledge about how technology can create different representations for a specific concept; it demands that the teacher be aware and understand how using specific technologies can affect learners' skills and understanding of the relevant concepts and content (Mason, 1998). TPK−technological pedagogical knowledge−implies familiarity with the range of technologies that can be integrated into teaching and understanding how their use can affect teaching methods.

In the current study, we focus on tools such as designated sites, applets, collaborative tools, calculators, and online spreadsheets such as Excel, tools that are in common use in schools. The literature indicates that using these tools allows students to be involved in their learning both independently and collaboratively, promotes students' thinking skills, and enable teachers to improve their pedagogy, starting with modes of presenting information and visual information and continuing with conducting research and student evaluation (Haspekian, 2014; Koh et al., 2014; Segal et al., 2018; Shin, 2022).

The literature shows that when teachers incorporate ICT into their teaching, it motivates their students' learning and achievements (Pozas & Letzel, 2021). There are three main factors that impact the use of ICT in teaching and learning processes, and these are "will" (a positive attitude), "skill" (self-efficacy and ability to use ICT), and "tools" (ease and extent of use) (Knezek &

Christensen, 2016). Teachers are more likely to use a specific technology when they are aware of its purpose and benefits and do not find it too complicated to use (Teo, 2011). A model regarding ease of use, TAM (technology acceptance model), suggests a technology's perceived usefulness and ease of use will influence teachers' use of the tool (Davis, 1989). "Usefulness" is the level at which a person believes a particular technology will improve performance; "ease of use" refers to the effort required to use it.

Lai and Bower's (2019) systematic review has indicated that analyses of how learning technology is used tend to focus on learning and less on affective and pedagogical aspects. However, the affective aspect cannot be ignored since it might impact teachers' intention to use technology in class (Joo et al., 2018). Also important is to give teachers time to experience and evaluate the appropriateness of ICT tools to teaching and learning so that they become comfortable using technology and its innovations (Davis, 1989; Knezek & Christensen, 2016; Joo et al., 2018).

Unfortunately, despite their awareness of the purpose, usefulness, and ease of use of particular technologies, teachers seldom use ICT in their teaching and prefer to stick to traditional methods (Urezm et al., 2018). In fact, the most common use of ICT is for administrative purposes (Krause et al., 2017). It seems that venturing into the world of innovative computer-mediated teaching still involves apprehension, hesitation, and anxiety. Some researchers (e.g., Balanskat et al., 2006; Perienen, 2020) argue that although educators appear to acknowledge the value of ICT in schools, difficulties continue to be encountered during the process of adopting these technologies.

There are three barrier levels affecting teachers' integration of ICT into teaching: teacher-level (lack of time, lack of confidence, resistance to change, lack of knowledge and skills, Pape & Prosser, 2018); school barriers (limited access to ICT, limited dedicated software, British Educational Communications and Technology Agency [BECTA], 2004; Pelgrum, 2001; Sherry & Gibson, 2002); and system-level (restrictive curricula, absence of appropriate ICT training). Note that according to 2018 Talis Report, only 56% of teachers received instruction on the use of ICT in teaching during their education and training, OECD, 2019b). As emphasized by Spiteri and Chang Rundgren (2020), teachers need support in order to integrate technology in their lessons according to school curriculum. But digital technology is not only a pedagogical tool for the teacher; it is also a way for students to experience mathematical objects and scientific phenomena virtually and interactively that surpasses what can be described in a book or on board (Leung, 2013; Widiyatmoko, 2018). For this reason, educators encourage introducing such technological means at an early stage of teacher training so that prospective teachers not only become familiar with how to develop content and pedagogical knowledge using technology but cultivate positive attitudes and confidence in their use (Huang & Zbiek, 2017).

Attitudes of Mathematics & Science Teachers Towards ICT

The role of the teacher is to initiate thinking events and give students time to think and develop their higher-order thinking skills (Miedijensky et al., 2021; Tabach & Slutzky, 2017). The use of ICT in mathematics and science education has the potential to change the classroom from a traditional one to an active and interactive one that can have a positive impact on students' motivation for learning (Areepattamannil & Santos, 2019). However, the beliefs of mathematics and science teachers have a great impact on their perception of their role in the classroom and their approach to teaching (Funkhouser & Mouza, 2013; Miedijensky, 2023; Pajaras, 1992; Prestridge, 2012) and researchers have found that teachers tend to adhere to their own perceptions regarding learning and teaching (Hativa & Goodyear, 2001; Kramarski & Michalsky, 2015). This might create a problem when it comes to embracing innovative technological environments that require a change in teaching-learning and the perception of the teachers' role.

Rap et al. (2020), in a study of chemistry teachers, reported negative attitudes regarding the shift to online teaching. The teachers in their study cited a low ability to apply pedagogical skills, technological challenges, difficulties interacting with students to encourage maximum engagement and participation, problems providing feedback, and difficulty creating collaborative learning assignments. The researchers concluded that teachers need more support to attain the technological pedagogical knowledge required to create successful integrative lessons. Nonetheless, teachers' attitudes regarding the integration of technology can change if they are given sufficient experience to appreciate its efficiency and ease of use. At the same time, efficient change may be related to the teacher's subject matter knowledge. Chiu and Churchill (2016) found that mathematics and science teachers were more likely to significantly improve their view on use of computers in classroom than language and humanities teachers. These changes may be implicitly influenced by discipline's culture, learning objectives, and teaching goals.

METHODOLOGY

Design

This study aimed to examine the change in the attitudes of in-service mathematics and science teachers toward the integration and use of computerized technological tools as a result of the COVID-19

pandemic. We used a quantitative retrospective study design (Hipp et al., 2020) that utilized a self-report questionnaire that was submitted online about six months after the breakout of COVID-19. The use of a retrospective survey was deemed justified as the responses were submitted in a timeframe that was relatively short enough so that they still remembered their usage patterns before the COVID-19 outbreak.

Participants

A convenience sample of 104 mathematics (n=86) and science (n=18) in-service teachers participated in this study. The teachers were contacted via social networks of mathematics and science teachers (e.g., Facebook, WhatsApp groups). Most teachers in Israel teach more than one class level: about half (48%) taught in an elementary and/or middle school and about half (52%) in middle school and/or high school. Most (49%) had 16 or more years of teaching experience, 30.8% had six-15 years, and 20.2%, one-five years' experience.

Data Collection

A 23-question validated questionnaire based on Haspekian (2014) was adapted for this study (Haspekian, 2014 studied the practices of mathematics teachers integrating ICT into their teaching). The original French was translated into English and then into Hebrew. To adapt it to the current study, we changed the references in the questionnaire to also include science teachers. Then we adapted the questions to the express purpose of the present study, that is comparing attitudes before and since the COVID-19 pandemic by repeating each set of questions twice, asking about their attitudes first before the pandemic and then during the pandemic. We also added some statements to assess to what degree teachers used technologies in their instruction (before and after the pandemic).

The questionnaire included the following:

(1) 10 questions to determine socio-demographic variables: gender, primary teaching language, teaching seniority (number of teaching years), discipline, institution, and habits regarding reading professional literature.

(2) One yes/no question regarding mathematics and science teachers' TK before and since the outbreak.

(3) A list of five ICT tools (for example: "applets") that were to be ranked based on the extent of the teachers' use of each tool before the pandemic (α=.824) and since its outbreak (α=.803).

(4) Three statements about the possible purposes of ICT in teaching (for example: "As a tool for creating a learning environment") to examine teachers' attitudes towards ICT in teaching before (α=.657) and during (α=.759) the pandemic.

(5) Four statements giving possible reasons for not incorporating technology into teaching. For example: "It takes too much preparation time" (α=.580).

For parts 3, 4, and 5, the teacher was requested to rank their level of agreement with each item/statement from zero (disagree) to three (strongly agree).

The adapted questionnaire was validated by three experts in mathematics education and two experts in science education plus an expert (PhD) on research methods and evaluation in education. The validity process involved discussing each item in the questionnaire after which changes, if required, were implemented until at least 80% agreement was reached. It was then tested in a pilot study with small groups of mathematics and science teachers after which the statement formulations were refined accordingly. The questionnaire was then distributed to the intended recipients via email and teachers' professional social networks.

Data Analysis

Data was analyzed using SPSS 25. Descriptive analyses included frequencies and percentages (for discrete variables) and means and standard deviations (for continuous variables). Correlations between discrete variables were analyzed using the $\chi 2$ test; between continuous variables using Pearson r correlation coefficient and Spearman ρ. Differences between paired variables were analyzed using paired-sample t-tests.

FINDINGS

Mathematics & Science Teachers' TK Before & Since Outbreak of COVID-19

Knowledge of ICT

The first research question sought to compare teachers' TK *before and during the COVID-19* pandemic. For this, we focused on the teachers' answers to the question: **Before the pandemic, did you know of any computer programs/environments for teaching mathematics/science that were accessible to students at the institution, where you teach? Are you more aware of such possibilities now?** 57.7% reported that they had such knowledge before the pandemic and 67.3% indicated having this knowledge at present, indicating a significant rise (χ^2=20.55, p≤.000).

A significant correlation (χ^2=9.48, p=.009) was found between teaching seniority (number of teaching years) and percentage of respondents who reported that they were aware of the existence of computer programs/environments for teaching mathematics or science *before* the pandemic: 10.0% of respondents with one to five years of experience, about a third (36.7%) of teachers with six to 15 years of experience, and about half

Table 1. Incorporation of technological tools in teaching before the COVID-19 pandemic (%)

Extent of use before COVID-19	Disagree	Agree a little	Mostly agree	Strongly agree
Calculator	13.5	22.1	20.2	44.2
Designated sites	4.8	19.2	36.5	39.5
Applets	7.7	18.3	35.5	38.5
Collaborative tools	9.7	31.7	29.8	28.8
Spreadsheet (such as Excel)	20.2	37.5	23.1	19.2

Table 2. Incorporation of technological tools in teaching since the outbreak of COVID-19 (%)

Extent of use since COVID-19	Disagree	Agree a little	Mostly agree	Strongly agree
Calculator	2.9	8.7	16.3	72.1
Designated sites	1.0	8.6	20.2	70.2
Applets	3.8	14.4	17.4	64.4
Collaborative tools	10.6	19.2	19.2	51.0
Spreadsheet (such as Excel)	15.4	21.2	30.8	32.7

Table 3. Difference in extent of incorporation of ICT in teaching before COVID-19 pandemic & since outbreak of COVID-19, & correlations between both measurements (n=104) (Range:0-3)

	Before COVID-19 pandemic		Since outbreak of COVID-19		Differences		Correlations	
	M	SD	M	SD	t(df=103)	p	r	p
Sum of incorporation (0-15)	9.30	3.62	11.51	3.30	-7.27	.000	.60	.000
Spreadsheet (such as Excel)	1.41	1.02	1.81	1.06	-4.72	.000	.67	.000
Applets	2.05	0.94	2.60	0.69	-6.35	.000	.45	.000
Designated sites	2.11	0.88	2.58	0.77	-5.92	.000	.52	.000
Collaborative tools	1.78	0.97	2.42	0.88	-7.11	.000	.51	.000
Calculator	1.95	1.10	2.11	1.06	-2.41	.018	.82	.000

(53.3%) with 16-years or more experience indicated that they had been aware of these options. A similar trend (although not significant, χ^2=4.74, p=.094) was observed regarding how they reported their knowledge of such options *since the pandemic*: 14.3% (one to five years' experience), about one-third (31.4%, six to 15 years), and about half (54.3%, 16 or more years).

Use of Specific ICT Tools

The teachers were asked to rank the extent of their use of specific computerized technological tools in their teaching *before* and *since the pandemic* (see **Table 1** and **Table 2**). The difference in the extent of ICT incorporation in teaching before and since the COVID-19 pandemic and correlations between both measurements are presented in **Table 3**.

Table 3 shows a significant increase ($t_{[103]}$=-7.27, p<.000) in the extent of integration of technological tools when comparing their use before the pandemic (*mean* [*M*]=9.30, *standard deviation* [*SD*]=3.62) and during (*M*=11.51, *SD*=3.30, range 0=none, to 15=use of all tools very much). A similar and significant trend was found for all the tools, however, during the pandemic, the tools that were most used were applets (*M*=2.60, *SD*=.69), designated sites (*M*=2.58, *SD*=.77), collaborative tools (*M*=2.42, *SD*=.88), and the calculator (*M*=2.11, *SD*=1.06). With respect to the spreadsheet, its use was relatively low before the pandemic (19.2% of respondents reported extensive use, *M*=1.41, *SD*=1.02) and this increased only slightly (to 32.7%, *M*=1.81, *SD*=1.06) during.

In addition, high positive significant correlations were found between the integration of technological tools in instruction before the pandemic and during (r=.60, p≤.000). The total extent of integration of each of the tools were tested separately, and all correlations were found to be high and significant (range of correlations r=.51-.82, p≤.000). The highest correlation (r=.82, p≤.000) was found with respect to calculators, meaning that this tool was used to about the same extent throughout. Applets, collaborative tools and designated sites had the lowest correlations (r=.45, r=.51, r=.52, respectively), i.e., they demonstrated the highest changes in extent of use.

With respect to the relationship between TK and its implementation, moderately positive significant correlations were found between "general knowledge of computer use" and its integration of technological tools both *before the pandemic* (r=.30, p=.002) and *during* (r=.35, p=.000). In other words, the more respondents knew about computer uses, the more they reported that they tended to incorporate technological tools into their teaching during both periods.

Mathematics & Science Teachers' Attitudes Towards Purpose & Usefulness of ICT Before & Since Outbreak of COVID-19

To answer the second research question, we analyzed the degree of the respondents' agreement (Likert scale zero-three) with statements regarding the use of computerized technological tools in teaching (**Table 4**).

Table 4. Teachers' attitudes toward purpose of ICT tools in teaching before & during pandemic (% marking each item)

Use of computerized technologies is appropriate	Before COVID-19 outbreak	Since COVID-19 outbreak	χ^2
To free students from basic calculations so that they can focus on thinking	60.6%	48.1%	17.59***
As an aid for struggling students	59.6%	46.2%	18.06***
As a tool for creating a learning environment	57.7%	64.4%	31.39***

Note. n=104 & ***p<.000

Table 5. Descriptive statistics of mathematics & science teachers' difficulties in integrating technological tools into teaching during COVID-19 pandemic (statements are in descending order of mean ranking)

	M	SD	DS	A	MA	SA
(1) I would love to incorporate computer technologies into teaching, but it takes too much preparation time!	**1.97**	1.07	14.4	14.4	30.8	40.4
(2) I decided to incorporate ICT into teaching, but it was so complicated to find enough computers for students (in class or at home for distance learning) that I gave up on idea.	**1.55**	1.06	20.2	27.9	28.8	23.1
(3) I have nothing against the use of ICT in teaching, but I have not been trained for that. If I had proper preparation, I would do it.	**1.27**	1.15	34.6	25.0	19.2	21.2
(4) I wanted to incorporate ICT into my teaching, but I had concerns and gave up (mostly I was afraid that some of students would probably do it better than me).	**.66**	.87	54.8	28.8	11.5	4.8

Note. n=104; M: Mean; SD: Standard deviation; DS: Disagree; A: Agree a little; MA: Mostly agree; & SA: Strongly agree

Table 6. Spearman correlations (ρ) between teachers' identification with difficulties & extent they incorporated ICT in teaching before & since outbreak of COVID-19 (presented in descending order of difficulty) (n=104)

	Incorporation of ICT in teaching (ρ)	
	Before COVID-19 pandemic	Since outbreak of COVID-19
(1) I would love to incorporate computer technologies into teaching, but it takes too much preparation time!	-.17	-.29**
(2) I decided to incorporate ICT into teaching, but it was so complicated to find enough computers for students (in class or at home for distance learning) that I gave up on idea.	.01	-.01
(3) I have nothing against the use of ICT in teaching, but I have not been trained for that. If I had proper preparation, I would do it.	-.01	-.11
(4) I wanted to incorporate ICT into my teaching, but I had concerns and gave up (mostly I was afraid that some of students would probably do it better than me).	.14	.07

Note. **p<.01

As indicated in **Table 4**, most respondents indicated that before the pandemic, they believed that the purposes of ICT were (in order) to

(1) free students from having to do basic calculations so they could focus on thinking,

(2) as an aid for struggling students, and

(3) as a tool for creating a learning environment.

Since the pandemic, more teachers see it as a means for creating a learning environment, with fewer focusing on its use as a calculation tool.

Comparing Difficulties in Integrating Technological Tools into Teaching Before & Since the COVID-19 Pandemic

Table 5 presents the results relating to the third research question. The average (mean) agreement for each statement is presented in descending order along with their standard deviations and the percentage of respondents who chose each level of agreement with these statements. **Table 5** shows that most of the respondents took issue with the idea of incorporating technology, whether because of the amount of preparation time required (over 70% agree/somewhat agree) or the complication involved (over 50% agree/somewhat agree). On the other hand, only about 40% responded that they would incorporate it if they would have proper training (the other 60% seemed to be indifferent). Although 15% expressed concern that they would not succeed, fully 85% indicated the opposite.

Correlation Between Teachers' Degrees of Identification with Difficulties & Extent of ICT Integration Before & Since the Pandemic

Spearman correlation coefficients were calculated between the teachers' degrees of identification with difficulties (see **Table 5**) and the extent of integration of computerized technological tools before and since the pandemic (**Table 3**). These are presented in **Table 6**.

A moderately negative significant correlation (r=-.29, p=.003) was found between level of incorporation of technological tools since the COVID-19 outbreak and

agreement with Statement 1 (M=1.97, SD=1.07, range zero-three):

> I would love to incorporate computer technologies into teaching, but it takes too much preparation time!

A negative but insignificant correlation (r=-.17, p=.089) was found relating to before the outbreak. However, very low and insignificant correlations (range:-.17 to .14) were found between incorporation of technological tools in teaching before and since the pandemic and agreement with the other difficulties: statement 2 (M=1.55, SD=1.06), statement 3 (M=1.27, SD=1.15), and statement 4 (M=0.66, SD=.87).

DISCUSSION

The purpose of this study was to present a picture that could help construct teaching and learning processes during emergencies by analyzing if the pandemic led to a change in teachers' attitudes toward the purpose of and difficulties involved in using technological environments.

Changes in TK as Result of ERT Due to the COVID-19 Pandemic

Despite the changes that the teachers were forced to undergo, only about 10% indicated that they had increased their TK as a result of the pandemic. Since the pandemic led to such an extreme change in the teaching platform worldwide (there was no alternative to online learning), such a small increase seems surprising. We can assume that this is because teachers had known already about available e-learning programs/environments for teaching mathematics/science prior to the outbreak and used the tools that they were already familiar with, making only minimal attempts to integrate any new ones.

It is worth keeping in mind that using technological tools for teaching requires a change in the teaching paradigm. Before the pandemic, integration barriers prevented ICT from being as widely adopted in formal education as it was in daily life (OECD, 2015). However, with the onset of the pandemic, teachers were forced to suddenly transfer their TK to online remote teaching, and it may be assumed that even teachers with well-established TK would have found this difficult since TPACK used for face-to-face teaching requires expansion and adaptation for distance ECT (Khatoony & Nezhadmehr, 2020; Rodríguez-Muñiz et al., 2021; Sepulveda-Escobar & Morrison, 2020;). Given the multitude of changes demanded at the time, it is logical to assume that teachers did not want to also begin learning about new platforms.

Nevertheless, even though our statistics show an increase of only about 10% in teachers' knowledge of the computerized tools available at their institution, since the outbreak of the pandemic, more teachers have defined themselves as users of technologies to a large extent, and the findings show a significant increase in the integration of applets and designated sites provided by their institution alongside those collaborative tools, online calculators and spreadsheets that were already widely used. This suggests that, given the absence of a classroom board, technological tools were crucially needed as demonstration tools.

Having to rely on ICT required new teaching skills and drastically changed the methods for teacher-student communication (Lin et al., 2013; National Research Council, 2013; Niess & Gillow-Wiles, 2017). It seems reasonable that to mitigate the sharp changes required in teaching paradigms, teachers looked to incorporate familiar technologies that supported their teaching (Bacher-Hicks et al., 2021). As we know from the literature (Hativa & Goodyear, 2001; Kramarski & Michalsky, 2015), teachers tend to adhere to their own, familiar way of teaching. Thus, they would be inclined to adapt the technological tools to their existing pedagogy (Tabach & Slutzky, 2017).

An additional observation was that teacher seniority is correlated with teacher TK. This suggests that time is needed to become familiar with technological educational programs and environments and all the more so to be able to integrate these tools and establish teaching and learning processes using them. These results are supported by the findings of Lim et al. (2018) that emphasize that in the first stage toward becoming a mathematics teacher, gaining an understanding of the structure of the relevant curriculum takes precedence over designing and creating lesson plans or implementing new pedagogical approaches for lessons. The ability to create lesson plans improves as teachers become more familiar with the curriculum over the years (Lim et al., 2018). Furthermore, teachers need specific training to integrate technology into their teaching to ensure they develop the digital technology to meet the demands of the curriculum (for a literature review, see Spiteri & Chang Rundgren, 2020).

Changes in Mathematics & Science Teachers' Attitudes About Purpose of Computerized Technological Tools

The results indicate that teachers' attitude about the purpose of computerized technological tools has shifted since the outbreak of the pandemic. Before, they used them primarily for performing calculations (that is, to release students from basic calculations so that they could focus on higher order thinking) and for supporting struggling students. However, as a result of the advent of COVID-19 and the change to ERT, teachers needed a platform with which to communicate with their students, and they turned to technology applications that they could easily and immediately integrate into

their lessons (Sepulveda-Escobar & Morrison, 2020). As a result, the main purpose of ICT tools became to create a learning environment suitable for online/remote teaching, and teachers increased their use of applets, designated sites, and collaborative tools. This agrees with the TAM model: the more teachers perceive technology to be "usable," the more frequently they will integrate it into their teaching (Davis, 1989). Consider that the use of one calculator app or another does not affect any change in learning, whether in class or remotely (via Zoom, for example).

On the other hand, in ERT, effective use of the classroom board, once the teachers' main way of demonstration, is severely hampered. Teachers had no alternative but to rely on dynamic applets–many already available for immediate use–to demonstrate processes, concepts, and procedures. As a result, teachers were required to quickly learn how to operate and communicate using various pedagogical technological tools.

With respect to spreadsheets, their use was relatively low *before the pandemic* but increased only to near moderate. This may be explained by the fact that teachers' knowledge of Excel (for example) was relatively limited and thus they did not commonly make use of the tool before the pandemic. Since they were not so familiar with the tool and given that teachers will tend to choose tools with which they are already familiar during ERT, they did not increase their use of spreadsheets, especially since their effective use requires a relatively high learning curve and requires both "user knowledge" (of the existing symbols and how to use them, etc.) and "creator knowledge" (how to create, develop and implement tasks for students in this environment). We may suppose, therefore, that the (relatively small number of) teachers who reported that they had integrated Excel into their teaching had, in addition to their *user knowledge*, well-developed *creator knowledge.* Teachers who did not have these skills were not, given the circumstances, available to learn how to create learning platforms with Excel.

Difficulties in Integrating Technological Tools into Teaching

It should go without saying that a teacher's perception of the difficulties in using technological tools will determine the extent of their integration. Our findings show that the most commonly expressed difficulty related to integrating technology was the time required to become familiar with the various technologies available, decide which one (if any) is appropriate, and create appropriate technologically driven lesson plans. This agrees with previous studies, which have emphasized that teachers require time to investigate technologies (Lin et al., 2012; Pape & Prosser, 2018) and evaluate their appropriateness to teaching and learning (Davis, 1989; Joo et al., 2018; Knezek & Christensen, 2016). Logistic difficulties were the second most common one noted by the respondents. Studies have shown the logistic problems are mostly school-level barriers such as limited access to ICT and lack of resources (Conole et al., 2008; Cox & Marshall, 2007). Third was a lack of appropriate ICT training (see also Goktas et al., 2009; OECD, 2019b). Having knowledge regarding the extent to which these barriers affect teachers may help in deciding how to alleviate them (Buabeng-Andoh, 2012). While TAM model points to the perceived usefulness and ease of use of a technology tool as factors in their use, the present study revealed another aspect: the availability of appropriate conditions, meaning that education systems, in their quest to encourage CIT, should consider the suitability of available conditions.

Given the sudden, almost "near instantaneous" changes in circumstances that arose as a result of the ERT due to the pandemic, it seems reasonable to assume that teachers were overwhelmed at the changes required and tried "to survive" by using only those tools that would allow them to quickly adapt to teaching in the virtual classroom. Anything beyond that had no time and place, and any technological tools requiring intensive or extensive knowledge to use them were less likely to be adopted. This indicates the importance of integrating ICT information into in-service and pre-service teachers' practice, providing intervention programs on the topic, and offering professional development workshops to deepen teachers' knowledge of how the use of technology can enhance their TPACK.

CONCLUSIONS & RECOMMENDATIONS

The accelerated development of technology over the past few decades involves numerous challenges that calls for intense changes in teaching and learning paradigms. Despite this, seven years ago, before the onset of the COVID-19 pandemic, such changes had not yet been widely adopted in formal education (OECD, 2015). According to our findings, this situation had persisted up to the time of the pandemic, meaning that ICT was being used only for trivial purposes: for the most part, the findings indicate that the purpose of integrating ICT in teaching was free students from basic calculations. Since the pandemic, more teachers see it as a means for creating a learning environment. Although most teachers understood importance of incorporating ICT into teaching, a significant portion claimed that they hesitated to do so either because they lacked the necessary TPACK for remote learning (i.e., their TPACK training focused only on face-to-face teaching) or they lacked sufficient preparation time for planning and implementing ICT into their lessons. These factors may have influenced their attitude to implementing computerized technology into their teaching.

However, the onset of the pandemic led–almost instantaneously–to the demand for distance teaching, leading to a significant need to integrate ICT tools, such as applets and designated sites, into their teaching. Nevertheless, as our results suggest, despite teachers' increased recognition of this need, they did not possess the necessary TPACK or other skills required. This is even more critical today, given the post-pandemic trend toward increased use of digital technology in the classroom or distance teaching. Improving this situation will ultimately lead to better learning opportunities for their students.

Technology and its use thereof is expanding at a rapid pace. Teacher training today should address the issues of how new technologies may be utilized by teachers to fit changing pedagogical goals. Our findings suggest that a change in the training of pre- and in-service teachers is called for and that TPACK given to teachers for face-to-face teaching must be expanded and adapted if they are to successfully engage in distance teaching or increase their use of ICT. This raises the need to consider how to best lead novice teachers to expand and deepen TK and TPK and, as a consequence to develop appropriate training and professional development programs. Indeed, the correlation we found between teacher seniority and TK indicates that attaining curricular, content, and pedagogical knowledge is required for integrating appropriate computerized teaching.

Our findings also indicate that lack of time is a factor in the teachers' hesitancy to use ICT. Thus, initiating timetable changes to allow adequate preparation time would be another way that ICT use could be expanded.

Our findings offer a first step in understanding mathematics and science teachers' attitudes toward ICT use in the classroom and how to improve it. Further studies are needed to identify factors that may hinder TPACK acquisition or the integration of ICT into teaching and how to mitigate them. For example, is it and if so in what way teachers' emotions may have an influence on their TPACK, an aspect that we will discuss in a future article.

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