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Characteristics and effectiveness of formal and informal teacher professional development for remote teaching of educators in different career stages

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Abstract

This mixed-method study examined formal and informal teacher professional development (TPD) processes in Remote Teaching (RT) context. Semi-structured interviews were conducted with 60 elementary homeroom teachers in early, middle, and senior career stages. The bottom-up analysis (N=2,537 statements) revealed two types of TPD: informal-spontaneous and formal-institutional. The findings highlight the need to strengthen technology-enhanced pedagogy in both formal and informal TPD, in order to optimize RT and technology-enhanced classroom learning. Informal training occurred through network and/or with colleagues. Teachers emphasized the contribution of online communication tools to their techno-pedagogical knowledge. They widely used digital tools for teacher-centered illustration and demonstration, while assessment and creation tools were less prevalent. Familiarity with collaborative, pedagogical, class-management tools and digital games occurred mainly in formal-institutional training.

Keywords: Teacher professional development (TPD); Informal-spontaneous and formal-institutional teacher training; Early, middle, and senior teacher career stages; Remote Teaching (RT); Teacher techno-pedagogical knowledge and skills; Online communication tools

Introduction

During periods of remote teaching (RT), teachers depended on their professional knowledge and skills, as well as on resources and facilities provided by their schools, local educational authorities, and ministries of education (Abaci et al., 2021; Chin et al., 2022). One of the main obstacles to technology integration in general and RT in particular is a

lack of adequate teacher training (Redmond et al., 2021). Many teachers have limited knowledge and professional skills in offering effective online instruction and in using a variety of digital tools (Avidov-Ungar & Herscu, 2020).

Educators can extend their informal learning activities into online spaces, enhancing their professional growth (Trust et al., 2020). Informal teacher professional development involves spontaneous and ongoing interactions with peers about instructional techniques in their daily work lives (Avidov-Ungar et al., 2023; Desimone, 2009). It also addresses educators' social, emotional, and identity needs, which are often unmet by formal programs (Marín et al., 2023; Trust et al., 2016).

The literature showed that schools with previous positive technology-enhanced learning were able to transition smoother from face-to-face to online teaching as well as teacher-student and peer-to-peer school-related communication (Eden et al., 2024; Pires & Moreira, 2015; Teidla-Kunitsõn et al., 2022). They are able to use online tools to create appropriate learning activities for their students (Redmond et al., 2021; Trust et al., 2020). On the contrary, schools without or with negative previous experience of digital learning experienced great difficulties in RT (Abaci et al., 2021). Therefore, transition to RT, as experienced during the COVID-19 pandemic or partial RT in routine times in the form of hybrid learning, emphasizes the need for immediate and extensive teacher professional development (TPD) (Abaci et al., 2021; Lockee, 2021) adjusted to the needs of teachers in different career stages (Avidov-Ungar & Herscu, 2020; Avidov-Ungar et al., 2023).

This study examined the contribution of TPD processes conducted by teachers in different career stages in formal and informal contexts during the first RT period of the COVID-19 pandemic (March-June 2020) compared with the second RT period (July-October 2020). This study was based on a conceptual framework for TPD which proposed teacher training adjusted to the digital era (Sancar et al., 2021; Tregubova et al., 2020).

Literature review

Professional development of in-service teachers for online learning

Despite the potential added value of technology to provide access to global learning and resources (Shamir-Inbal & Blau, 2022), teachers often demonstrate limited knowledge and skills for creating effective technology-enhanced instruction (Redmond et al., 2021). Teacher professional development helps teachers deepen their understanding of teaching-learning processes (Avidov-Ungar & Shamir-Inbal, 2017), and improve their professional techno-pedagogical knowledge and skills (Wuryaningsih et al., 2018).

Importantly, online teaching requires tailored TPD designed specifically for the online teaching environment, since successful teaching in a face-to-face classroom does not

automatically transfer to online environments (Philipsen et al., 2019). Namely, online teaching requires different skills from the face-to-face teaching environment (Avidov-Ungar et al., 2020; Weiser et al., 2018). Thus, preparation and support for online teaching should go beyond teachers' preparation for face-to-face classroom teaching (Wuryaningsih et al., 2018).

Effective TPD processes, according to the recent Tregubova et al. (2020) conceptual framework, suggest five main steps in teacher-training. This teacher-training framework is based on five principles: 1) Assess teachers' needs in terms of their digital literacies, knowledge of digital technologies, and understanding of how to use these technologies to teach effectively. 2) Design to meet individual needs of teachers, considering prior knowledge, skills, and experience. 3) Encourage collaborative learning experiences and sharing ideas in a community of practice. 4) Use digital technologies to create engaging and interactive learning experiences. 5) Help teachers learn and grow based on evidence of what works best.

Further, Sancar et al.'s (2021) framework suggests that TPD should be research-based, tailored to specific needs of schools, and provide teachers with support and autonomy. It should also help teachers develop the knowledge and skills they need, to implement them effectively to be sustained over time and provide opportunities to collaborate and learn from each other's expertise.

This study presents TPD as a lifelong learning process that covers both **formal and informal practices**, which refers to ongoing learning and training that teachers engage in to improve their skills and knowledge. (Avidov-Ungar et al., 2023; Wuryaningsih et al., 2018). Formal and informal TPD are both valuable for teachers. Formal TPD typically takes place in a structured setting, such as a workshop or online course and can offer the latest best practices. Informal professional development can take place in a variety of settings, such as a peer network for sharing ideas and reflecting on pedagogical practices (Lockee, 2021; Pires, 2021). In RT during the pandemic teachers spontaneously adopted a variety of informal ways to interact with colleagues, mainly through social media platforms, in order to acquire useful skills for RT (Avidov-Ungar et al., 2023; Lockee, 2021; Trust et al., 2020). In addition to informal peer learning, teachers were offered some formal TPD processes provided by the Ministry of Education (MoE, 2020). TPD relevant to the rapid transition towards RT must address technical skills and tools and online pedagogy

Fig. 1 Five steps in effective teacher training process

according to local needs and national standards, including curriculum standards, professionalism, and leadership (Lockee, 2021; Pires, 2021).

Professional development in teachers' "career cycles"

Teachers are required to improve their knowledge and competencies on a regular basis as part of lifelong learning (Avidov-Ungar & Shamir-Inbal, 2017; Chin et al., 2022). TPD can support teachers in sustainable careers (Chin et al., 2022), beginning with teacher education programs and continuing throughout their professional lives (Avidov-Ungar & Herscu, 2020; Sancar et al., 2021; Wuryaningsih et al., 2018). The TPD process is affected by teachers' professional characteristics, e.g., seniority in teaching, expertise, experiences, professional awareness, as well as by process-related characteristics, e.g., expectations and openness to innovation and change (Lockee, 2021).

Studies examining teachers' careers discuss a "career cycle" including stages from entering the profession until retirement (Avidov-Ungar & Herscu, 2020; Avidov-Ungar et al., 2023; Furner & McCulla, 2019). This cycle includes three major teacher career-stages based on their years of teaching experience: early - 1-7 years of seniority, middle - 8-23 years of seniority, and senior stage - 24+ years in teaching (Avidov-Ungar & Herscu, 2020; Furner & McCulla, 2019). Teachers in different career stages have different needs, abilities, and inclinations to learn new pedagogical approaches and also differ by their willingness to incorporate classroom changes (Philipsen et al., 2019).

In order to understand teacher learning and professional development that occurs in multiple online contexts, both formal and informal, this study examined the effectiveness and contribution of such TPD processes for RT during the first period of the COVID-19 pandemic (March-June 2020) as compared with the second RT period (July-October 2020). The study related to teachers in different career stages, since their level of professional experience may affect the effectiveness of untraditional TPD during the RT. Accordingly, the research questions were:

1. What are the characteristics of the TPD of teachers in different career stages in relation to informal-spontaneous and formal-institutional aspects of training and with comparison between the two periods of RT?
2. What is the contribution of TPD to the development of teachers' techno-pedagogical knowledge and skills of integrating digital tools in relation to their different career stages and with comparison between the two periods of RT?

Methodology

This study used a mixed-method approach, based on a qualitative-thematic analysis of teachers' self-reports through interviews. The qualitative data were quantified in order to enable a high-level overview. The statistical analyses of qualitative data were used as a

complementary method rather than as a replacement of the qualitative analysis. It was used for counting themes and presenting them in tables, recognizing patterns within the qualitative results, and identifying deviations from these patterns (Collins, 2021; Fakis et al., 2014). Using a mixed-method approach allowed researchers to conduct in-depth analysis, identify common expressions and recurring themes, merge themes and categories, and point to the overlap between themes (Yin, 2015).

Participants

The participants were 60 elementary school homeroom teachers in Israel in three different career stages. The study focused specifically on homeroom teachers, since they teach the majority of class subjects and spend a relatively high number of hours with the students, especially during RT in emergency situations such as the COVID-19 pandemic. The data collected included general information about the size of the school where the interviewees teach, school staff readiness for RT, demographic information such as teacher's gender, age, seniority, and education, and areas of specialization, as well as other positions in the school. Table 1 presents the demographic characteristics of the participants.

School staff readiness for RT was measured through a content analysis of teacher statements and was classified into three subcategories - low, moderate, and advanced readiness according to the following specifications:

- **Low readiness** of school staff (14; 23.33% in the first RT period and 0 in the second period) - expressed when the school did not have a suitable infrastructure or when teachers could not cope with the initial load and reported helplessness due to lack of techno-pedagogical knowledge. "No one was ready for it.… It is true that on a daily basis we give students technology-based tasks. Sometimes we ask them to prepare presentations, but that is not the main method of learning. This situation caught us unprepared." (T21)

Table 1 Demographic characteristics of study participants (N=60)

General criteria	Characteristics	N	%
Gender	Female	55	91.67%
	Male	5	8.33%
Career stage (teaching seniority)	Early (7-1 years)	20	33.33%
	Middle (23-8 years)	20	33.33%
	Senior (24+ years)	20	33.33%
Education level	Bachelor's degree	29	48.33%
	Master's degree	31	51.67%
School size	Small	3	5.00%
	Medium	26	43.33%
	Large	31	51.67%

- **Moderate readiness** of school staff (31; 51.67% during the first RT period and 20; 33.33% during the second one) - expressed when there was no sufficient preparation, a lack of training courses, or lack of equipment. However, since there was a digital infrastructure, the school was able to organize and deal with the challenge. "The school had the ability to conduct technology-enhanced learning; there were computers in every classroom. There was encouragement to use them, but no curriculum and TPD for teachers to integrate them. We learned throughout the RT process." (T15)
- **Advanced readiness** of school staff (15; 25% during the first RT period and 40; 66.67% during the second period) - expressed when there was prior training for the team, familiarity with a variety of technological tools, an appropriate infrastructure, and the ability to organize well and quickly for emergency learning. "Once we knew we were going to move to online learning, the school was ready. The kids got tablets or laptops and used them to connect to the internet and learn." (T33)

Instruments and procedure

The study received approval from the Institutional Ethics Committee and from the Ministry of Education. Teachers who deal with technological innovation and pedagogy in education were recruited through social media. The announcements were posted in Hebrew in different open Facebook groups for school teachers dedicated to a variety of pedagogical issues. Semi-structured interviews with the participants were conducted by a research assistant with expertise in learning technologies and in conducting qualitative research, who was trained by the researchers. The interviews were conducted through a Zoom videoconferencing platform, recorded, and analyzed. The average interview duration was 60 minutes and allowed exploring concepts and considerations for integrating technology in classrooms.

During the interviews, participants were asked to describe the contribution of TPD to their professional grows, SRL processes, and techno-pedagogical knowledge they acquired during the two periods examined. For example, the following questions explored the learning process during TPD: "Describe how your learning took place in the transition to remote teaching in each of the two periods?" "Was the learning spontaneous (alone/with colleagues/from internet sources) or institutionalized (TPD center/school/ministry of education) in each of the two periods?" Example of questions focused on self-regulation were: "What goals did you set to yourself in learning during each of the two periods?" "Did you achieve these goals?" Example of a question that explored the contribution of TPD to pedagogical-technological knowledge is: "How did the professional development you participated in contribute to the expansion of your pedagogical-technological knowledge in each of the two periods? Describe how this manifests itself in each of the two periods." Example of a question that explored implementation of the TPD content in the participants'

classroom is: "How was what you learned during each of the two periods implemented in your online teaching?"

The participants' responses were mapped using a bottom-up thematic analysis in order to reveal the main categories and subcategories. This analysis enabled the creation of categories to cross-reference the types and characteristics of professional development and to understand their use in actual teaching. The data collected was classified into the first RT period in Israel in March-June 2020 or the second period in July-October 2020. In addition, teachers were distinguished according to their career stage (early, middle, and senior). Details of the categories and the method of analysis are presented below.

To ensure inter-rater reliability of teacher statements (in both bottom-up content analysis and top-down systemic analysis), 25% of the statements were analyzed by a second rater and the agreement level was high, Cohen's Kappa=.85. Note that the resulting coding is not exclusive, i.e., the same statements could be attributed to several categories. For example, "We were exposed to a lot of digital tools that could be taught remotely, both synchronously and asynchronously. I felt that when I used these tools, my teaching became better and more accessible to students. They participated, enjoyed, and were absorbed in learning." (T1). This statement appears under a sense of professional achievement and under acquisition of a variety of tools.

Thematic analysis of the interview transcriptions revealed 2,537 bottom-up statements grouped into two main categories:

Characteristics of TPD training (N=1,344, 53%). This category included two subcategories that addressed the TPD of teachers: informal-spontaneous learning and formal-institutional learning. Teachers' learning efficiency in both aspects was classified as low, moderate, or high efficiency according to the following specifications: Low training efficiency was classified when training content did not help teachers implement digital learning. Sometimes it created unnecessary confusion and burdens, mainly because the training was not suitable for the needs of the teachers. Moderate training efficiency was classified when the training only partially helped to deal with the situation. There were certain benefits, but at the same time teachers reported many limitations. High training efficiency was classified when training helped the teachers implement what they had learned into practice. The content learned was useful and of professional value to the teachers.

The contribution of TPD training (N=1,193, 47%). Teachers addressed two aspects defined as subcategories. The first subcategory was technological tools learned during training: communication tools, illustration and presentation tools, accessibility tools, creation tools, collaborative tools, pedagogical management tools, assessment tools, and gaming tools. The second subcategory was the contribution of TPD to techno-pedagogical knowledge, such as acquiring applicable knowledge using digital tools and learning

environment, experience in problem-solving, exposure to tailored assessment methods, and addressing special needs and emotional responses.

Findings

Characteristics and effectiveness of teacher professional development

The first research question dealt with the characteristics of the TPD of teachers in different career stages in relation to informal-spontaneous and formal-institutional aspects of training and with comparison between the two RT periods. In this category, teachers specified 1,344 statements, 53% of all statements. Formal learning refers to the various TPD courses offered by educational institutions to teaching staff throughout their professional careers. Characteristics of informal learning refers to the natural dynamics of the teacher and his/her ways of teaching during the RT periods. Effectiveness of formal and informal training were categorized into three levels: low, moderate, and high, as explained in the Method.

The categories were attributed to the RT period (first and second) and the teachers' career stages (early, middle, and senior). In order to examine the significance of the differences in the number of statements observed in each group according to the RT period and according to their career stages, we performed a Chi-Square goodness-of-fit test and used an index of Standardized Residuals. Details of the representative categories and statements are presented in and after Table 2.

Informal learning- The interviewees revealed two modes of informal learning:

A. **Independent online learning**- Sudden transition to RT encouraged teachers to search for useful online sources: "*The internet was flooded with information and materials for independent learning, and it really opened up the option to learn by myself through YouTube and various websites*." (T10)

B. **Peer learning**- The teachers, especially during the first RT period, were assisted by their colleagues in learning suitable methods and tools: "*Peer learning made a very significant contribution. When I could not learn independently, I turned to colleagues from other classes and other schools.*" (T14)

The first type of informal learning, independent online learning, was significantly more prevalent than the second type - peer learning. Moreover, during the first RT period teachers conducted significantly more informal learning of both types, as compared to the second RT period. In addition, the higher teaching seniority was, the higher the level of informal learning reported by teachers.

Table 2 Characteristics and effectiveness of the formal and informal TPD (N=1,344)

Category	Subcategory	N	Standardized Residuals	RT period		Career stage		
				Period I	Period II	Early	Medium	Senior
Characteristics of informal learning N=551, 41%	Independent online learning	**311**	**+2.14**	**194**	117	74	**119**	**118**
				X^2 (1) = 29.53, ***p*=.000**		X^2 (2) = 9.83, ***p*=.002**		
	Learning with peers	240	-2.14	**160**	80	62	76	**102**
				X^2 (1) = 37.26, ***p*=.000**		X^2 (2) = 7.61, ***p*=.006**		
	X^2 (1) = 9.148, ***p*=.002**							
Effectiveness of informal learning N=122, 9%	High	**99**	**+9.15**	52	47	29	40	30
				X^2 (1) = 1.21, *p*=.271		X^2 (2) = .965, *p*=.326		
	Moderate	15	-4.03	**13**	2	5	6	4
				X^2 (1) = 7.89, ***p*=.005**		X^2 (2) = .052, *p*=.819		
	Low	8	-5.12	8	0	3	3	2
				-		-		
	X^2 (2) = 126.11, ***p*=.000**							
Characteristics of formal training N=456, 34%	In-school TPD	**209**	**+15.26**	58	**151**	64	71	74
				X^2 (1) = 31.08, ***p*=.000**		X^2 (2) = .164, *p*=.685		
	TPD in teacher training center	88	+1.38	20	**68**	29	30	29
				X^2 (1) = 20.81, ***p*=.000**		X^2 (2) = .00, *p*=.989		
	No TPD	70	-.69	**58**	12	20	27	23
				X^2 (1) = 36.13, ***p*=.000**		X^2 (2) = .291, *p*=.589		
	Ministry of Education TPD	64	-1.38	35	29	9	19	**36**
				X^2 (1) = 1.51, *p*=.218		X^2 (2) = 14.23, ***p*=.000**		
	Training by supervisors	**20**	**-6.42**	5	**15**	6	4	10
				X^2 (1) = 3.88, ***p*=.049**		X^2 (2) = 1.34, *p*=.247		
	Private external TPD	**5**	**-8.14**	2	3	1	1	3
				-		-		
	X^2 (5) = 344.61, ***p*=.000**							
Effectiveness of formal training N=215 16%	High	**140**	**+8.01**	31	**109**	53	**32**	55
				X^2 (1) = 34.672, ***p*=.000**		X^2 (2) = 4.17, ***p*=.041**		
	Moderate	38	-4.21	8	**30**	10	16	12
				X^2 (1) =10.27, ***p*=.000**		X^2 (2) = .501, *p*=.479		
	Low	37	-33.4	16	21	18	8	1
				X^2 (1) = .209, *p*=.647		X^2 (2) = 2.44, *p*=.118		
	X^2 (2) = 97.74, ***p*=.000**							

*Note: A Chi-Square test was not performed on the table cells that did not meet the test assumption.

Formal learning was reflected in the various courses offered during the RT. The internal school training, particularly during the second RT period, was significantly more common than all other institutional training. "*The principal initiated a TPD course of thirty hours, in order to advance the teaching staff and assist with various difficulties that we confronted when teaching remotely.*" (T1) Other TPD courses were also conducted by an external teacher education center and by the Ministry of Education. The references to TPD conducted by supervisors and by external private entities were significantly fewer than to the other training courses. Among the statements which referred to TPD, 70 statements revealed that there was no kind of institutional training at all, especially throughout the first RT period. "*During the first period I had very little organized TPD training. I had to learn how to conduct lessons remotely, especially in mathematics. I needed to learn how to use study aids and illustrations to teach students in the best way possible*." (T43)

The effectiveness of formal and informal TPD

The effectiveness of formal and informal training was classified into three levels (low, moderate, and high) through content analysis of teacher reports. In both types of training, formal and informal, training efficiency from the perspective of teachers was categorized significantly more as high compared to medium or low levels of training efficiency (X^2 (2) = 7.03, p=.008). However, the effectiveness of formal training was classified as significantly higher than the efficiency of informal learning.

Low level of training efficiency was perceived when training content did not help teachers implement digital learning. Sometimes it created unnecessary confusion and burdens, mainly because the training was not suitable for the needs of the teachers. One of the teachers presented in the following way the informal training processes: "*At the beginning, what was missing mostly was training that was more suitable for me. I was looking for tutorials suitable in terms of knowledge, but at first everyone dealt with the basic tools, and this did not suit me*." (T18) Another teacher described institutional training processes in the following manner: "*This training in the second period exposed me to more digital tools. The training itself was not structured enough, and I had a very difficult time studying. It did expose me to tools, but I did not really learn how to use them properly with my students*." (T6)

Moderate training efficiency was perceived when training partially assisted in dealing with the situation. There were some benefits, but also many limitations. For instance, one participant remarked during informal training: "*It would be nice having someone to help me understand how to implement the training and use the tools properly. I was overloaded with tools.*" (T22) The institutional training efficiency was classified as moderate during the first RT period significantly more than during the second period. An illustration from institutional training feedback is as follows: "*During the second period, the instructor*

spoke to us about how to construct blended lessons and how to manage Zoom lessons and useful tools in synchronous meetings. I was familiar with some of the apps, but she also introduced new tools." (T8)

High training efficiency was perceived when the training helped teachers to apply in practice what was learned. The content learned was useful and held professional value for the teachers. The effectiveness of institutional training was reported as significantly higher during the second period when compared to the institutional training courses in the first period. For instance, in informal training feedback, one participant remarked: "*Peer learning really helped me in teaching. The teachers gave us tips from their experience about how to organize the groups in a slightly more heterogeneous and correct way, how to organize them by levels, and what learning materials to use. We received a lot of ready-to-use materials.*" (T59) As for the institutional training feedback, one of the participants stated: "*In the second period we learned new software that could be used to teach new topics, practice them, and to conduct a formative assessment. Things like Google Classroom, World-Wall, and Teacher-Made apps, and things I did not know that were really important and helped me with distance learning.*" (T4)

The contribution of teacher professional development (TPD)

The second research question dealt with the contribution of TPD to the acquisition of digital tools and techno-pedagogical knowledge of teachers in relation to their different career stages and with comparison between the two RT periods. This category yielded 1,193 teacher statements, 47% of all statements. The first aspect in this category dealt with the contribution of training to learning technological tools for RT, while the second aspect explored the TPD contribution to techno-pedagogical knowledge. A Chi-Square test for goodness-of-fit was performed in order to examine the significance of the differences in the number of statements observed in each subcategory according to the RT period and the teacher's career stage (Table 3).

Below are details of the subcategories with representative statements:

Technological tools learned during the training- The teachers, in both formal and informal learning, reported the various digital tools they learned through their TPD and used during RT periods. Their references to communication tools were significantly more frequent than to other technology tools. In addition, references to assessment, production, and creativity digital tools were much less frequent among most of the teachers. This data is detailed below.

A. **Communication tools**- This was the most common subcategory, especially during the first RT period and with senior career stage teachers. These teachers reported mostly on the use of the Zoom application as a tool for managing lessons and WhatsApp as a

Table 3 The contribution of TPD training (N=1,193, 47%)

Category	Subcategory	Total	Standardized Residuals	RT period		Career stage		
				Period I	Period II	Early	Medium	Senior
Technological tools learned during training N=644, 55.5%	Communication tools	**209**	+13.83	**142**	67	50	**78**	**81**
				X^2 (1) = 36.76, ***p*=.000**		X^2 (2) = 8.11, ***p*=.018**		
	Collaborative tools	99	+1.76	37	**62**	22	33	**44**
				X^2 (1) = 3.70, ***p*=.055**		X^2 (2) = 7.33, ***p*=.026**		
	Illustration and presentation	88	+.55	43	45	33	22	33
				X^2 (1) = .122, *p*=.775		X^2 (2) = 2.75, *p*=.253		
	Pedagogical management	87	+.44	30	**57**	20	**40**	27
				X^2 (1) = 5.47, ***p*=.019**		X^2 (2) = 7.10, ***p*=.023**		
	Gamification tools	64	-2.09	13	**51**	27	15	22
				X^2 (1) = 17.58, ***p*=.000**		X^2 (2) = 3.40, *p*=.182		
	Accessibility to digital content	54	-3.18	25	29	15	19	20
				X^2 (1) = 0.10, *p*=.917		X^2 = .77, *p*=.678		
	Assessment tools	**34**	-5.38	8	**25**	10	7	16
				X^2 (1) = 6.86, ***p*=.009**		X^2 (2) = 3.81, *p*=.148		
	Creation tools	**29**	-5.93	8	**21**	11	8	10
				X^2 (1) = 4.38, ***p*=.036**		X^2 (2) = .482, *p*=.786		
	X^2 (7) = 273.4, ***p*=.000**							
Contribution of TPD to applicable techno-pedagogical knowledge N=529, 44.4%	Exposure to variety of technological tools	**262**	+18.51	90	**172**	68	91	**103**
				X^2 (1) = 66.97, ***p*=.000**		X^2 (2) = 7.24, ***p*=.027**		
	Applicable methods in using technological tools	**150**	+6.58	46	**104**	40	**70**	40
				X^2 (1) = 16.06, ***p*=.000**		X^2 (2) = 12, ***p*=.002**		
	Problem-solving ideas	37	-5.45	20	17	8	**19**	10
				X^2 (1) =.739, *p*=.390		X^2 (2) = 5.56, ***p*=.062**		
	Confident use of learning environments	35	-5.66	15	20	11	8	16
				X^2 (1) =.241, *p*=.623		X^2 (2) = 2.8, *p*=.247		
	Addressing special needs and emotional responses	29	-6.3	13	16	11	8	10
				X^2 (1) =.058, *p*=.815		X^2 (2) = 482, *p*=.786		
	Exposure to tailored assessment methods	16	-7.69	3	**13**	5	4	7
				X^2 (1) = 5.12, ***p*=.024**		X^2 (2) = .875, *p*=.646		
	X^2 (5) = 546.63, ***p*=.000**							

*Note: A Chi-Squared test was not performed in cases that did not meet the test assumption.

continuous communication tool. “During the first period of RT we had no TPD. We had very little institutional guidance on how to use Zoom and had to learn very technical things in order to be able to communicate remotely with parents and students.” (T10)

B. **Collaborative tools**- References to these tools were significantly more common regarding the second RT period and among teachers in their senior career stage. Teachers used collaborative tools, such as shared documents on *Google Drive* or *Microsoft office*, and digital notice boards- *Padlet* or *Canvas*. “*In the second period I had already learned how to use various collaborative tools. After some practice, I saw that they were relatively easy to implement*.” (T16)

C. Presentation tools- These included videos, word clouds, presentations, educational subject content, and presentation of subject-matter workbooks and digital books. “*During the second period, I used Zoom breakout rooms and also Yisumatica, which is the best website for teaching mathematics. This site helped me greatly in demonstrating the mathematics content we learned*.” (T20)

D. Pedagogical management- Teachers, especially those in their middle career stage and in the second RT period, referred to their use of *Google Classroom* for learning management and used *Google forms* for tracking and mapping students’ learning. “*I already knew how to use Google Classroom, but never really used it before. During RT we used it regularly. This digital platform enabled me to conduct much more sophisticated and well-organized teaching processes*.” (T10)

E. Creating gamification- During the second RT period there was a significantly high number of teachers who created a variety of digital games, such as puzzles, quizzes, and memory games. “*I found many digital platforms where I could create my own games, and there were also many existing games which I could make use of. These are tools which I am sure I will continue to use later*.” (T10)

F. Digital content tools- Teachers used these tools to access the subject-matter content to students or to adapt learning settings. “*I learned to integrate tasks developed by digital content providers. Before, I did not know that it was possible and that this content was even available... In addition, I became aware of and gradually started to use databases of learning materials available on the Ministry of Education’s portal*.” (T14)

G. Assessment tools- These tools included tests using Google Forms, widget practice, and assessment tasks in educational subject content. “In the second period I used videos with survey questions, creating trivia questions, and using Mentimeter and Padlet. We also created a test in Google Forms.” (T14)

H. Creation tools- These tools were used to produce and create presentations, questionnaire forms, concept maps, videos, and comics. “*The TPD contributed to mastering my skills in using these tools. My ability to produce and create with these tools*

increased from medium to advanced. My previous pedagogical knowledge helped me move forward to RT much easier and more effectively." (T28)

Contribution of TPD to applicable techno-pedagogical knowledge- Teachers addressed six main contributions of the training to their techno-pedagogical knowledge:

1. **Exposure to a variety of technological tools**- The interviewees were exposed to a variety of technological tools significantly more during the second RT period. Their references to exposure to technological tools were statistically significantly higher than found in any of the other aspects (Standardized Residuals: +18.51), which helped the participants in RT. Not surprisingly, the data shows that the higher the teachers' seniority, the more they addressed exposure to technological tools. These tools enhanced their lessons and assessment tasks. "*An internal school training was a techno-pedagogical course that introduced new digital tools and improved our proficiency in RT. This was much more significant in the second RT period*." (T47)
2. **Pedagogical usage of technological tools-** Many statements addressed the mastery of digital apps and adaptation of teaching methods to the digital classroom in a more creative, interesting, and efficient way. "*Together with other teachers from my school, I took a course dealing with RT of core subject-matters. We acquired digital tools and skills that helped me during the second period to make my teaching in these subjects more interesting and interactive*." (T14)
3. **Problem-solving**- Teachers acquired creative ideas for dealing with pedagogical and technological problems they faced during RT. The middle career teachers reported more problems than their colleagues: "*I learned how to differentiate tasks for diverse learner levels, to break teaching down into smaller parts, and how to encourage frustrated online students*." (T3)
4. **Confident use of learning environments-** The teachers felt in control of using various technologies in the online learning environment. "*In the first RT period I felt that I acquired skills and used tools in a minimal way. In the second period I had much more confidence, and I used the tools in a more sophisticated manner, which enhanced my teaching*." (T15)
5. **Development of capacity for special needs-** There was little attention to students with special needs and emotional challenges. "*I did not only set a goal to learn more about digital tools, but also how to connect with students. I could create open communication in order to understand what's going on at home*." (T58)
6. **Exposure to tailored assessment methods**- The smallest subcategory (Standardized Residuals: -7.69) referred to the contribution of tailored techno-pedagogical assessment methods. "*A colleague told me that she opened a digital notebook for each student. This helped her communicate with students and monitor what each one had done. I asked her to teach me... This was very effective peer learning*." (T9)

Discussion

This study examined the characteristics of formal and informal professional development and their contribution to RT. The study participants were 60 homeroom teachers who were in different career stages and related to two different RT periods.

Teachers in different career stages in informal-spontaneous and formal TPD

Regarding the *first research question*, teachers reported that two types of TPD took place during the first and second RT periods: informal-spontaneous training and formal-institutional training (1,344 statements, 53% of all statements). Informal TPD was based mainly on self-directed and peer learning. Formal TPD included internal school initiatives, training at external teacher centers, and online training organized by the Ministry of Education (MoE).

Formal training plays an important role in teachers' professional development aimed to help teachers in dealing with online teaching challenges during routine times (Shamir-Inbal & Blau, 2022) and in particular during RT periods (Trust et al., 2020). The TPD frameworks used in this study (Sancar et al., 2021; Tregubova et al., 2020) suggest components for effective formal training that are research-based, sustained, comprehensive, disseminated, contextualized, supportive, and collaborative, and can be integrated with technology use in a meaningful way to enhance teachers' learning experience. However, this study raises concerns about the differences between the characteristics of formal and informal training regarding the two remote teaching (RT) periods and between the teachers' career stages. At first, a large part of the effort was left to individual, informal learning instead of institutional training, and teachers received little formal preparation for the immediate use of ICT for educational purposes. This lack of formal professional training was especially observed during the first RT period (Rodríguez-Muñiz et al., 2021). Thus, most of teacher learning during this period was informal and mainly through the network and/or with colleagues. This informal self-directed learning was perceived by the participants as highly effective TPD and helped them to apply the acquired knowledge and skills.

During the first RT period, it was found that middle and senior teachers used informal training in the form of online independent learning and/or learning with their colleagues more than early career teachers did. Probably because senior teachers may have confidence in their professionalism and position in school and thus are not afraid to seek help. Moreover, senior teachers emphasized the importance of their participation in TPD, especially for RT. This attitude, which includes the readiness to gain personal development, shows that these teachers are not suffering from burnout and are still driven to learn new methods. Moreover, it can be assumed that their rich teaching experience greatly benefits them (Day et al., 2008). This finding is different from previous studies, which argued that

teachers in their early career stage expressed themselves as more open to innovation and technology changes than senior teachers, while senior teachers might see themselves as professionally competent and therefore not feel the need to learn new skills (Avidov-Ungar & Herscu, 2020).

Among the types of formal training which took place during RT periods, in-school training was the most common, probably because within their school, teachers can best develop their skills focused on techno-pedagogy, active learning, and learning content (Chin et al., 2022). The second common type of formal training was training conducted in regional training centers. TPD from these institutions took place, according to the teachers, mainly during the second RT period, and their perceived effectiveness during this period was significantly higher. Unfortunately, even though there was a great need for formal training, especially in the first period, as has been described in different studies and places (Chin et al., 2022; Pires, 2021), this essential training was not common during that time.

TPD and the development of teachers' techno-pedagogical knowledge and skills

The *second research question* examined the contribution of teacher training and professional development to classroom application. In this category, we gathered 1,193 statements, 47% of all statements. Teachers detailed the contribution of training in learning technological tools and in acquiring new techno-pedagogical knowledge. This knowledge is essential in order to develop teachers' skills, attitudes, and expertise, and to become prepared for RT instruction (Al-Naabi et al., 2021). This is consistent with previous studies claiming that acquiring a variety of digital tools may help improve teaching processes (Chin et al., 2022). Whether in formal or informal training, teachers reported that during this period they acquired a variety of technological tools that they used remotely for their online teaching. These findings are consistent with the conceptual frameworks we used (Sancar et al., 2021; Tregubova et al., 2020), which emphasizes the importance of technology-enhanced training content and skills.

Digital teaching skills and strategies required more than just learning how to use these tools. Teachers also needed to innovate their pedagogical practices and create engaging online learning experiences for their students (Chin et al., 2022). However, the schools' readiness for applying technology in the educational system was found to be low. This finding is consistent with previous studies' claims that, in terms of school readiness for distance learning, the schools were not ready enough to integrate online teaching (Asio & Bayucca, 2021). During the first RT period, teachers focused mainly on learning quickly how to use essential digital communication tools, especially Zoom videoconferencing. Similarly, in both periods, teachers looked for ways to use digital tools for illustration and demonstration, skills that characterize the traditional teacher who sees him/herself as a 'sage on the stage' (Hadad et al., 2021, 2024; Kasperski et al., 2023; Porat et al., 2023;

Shamir-Inbal et al., 2023; Yondler & Blau, 2023). However, familiarity with collaborative, pedagogical, and management tools and digital games occurred mainly during the second RT period. Unfortunately, teachers reported less use of assessment tools and digital creation, probably because these were learned mostly during the second period. This is consistent with previous studies, which claimed that only a small number of teachers addressed assessment methods as part of the digital teaching-learning process (Hodges & Barbour, 2021; Shamir-Inbal & Blau, 2021). Thus, as emphasized by the study frameworks (Sancar et al., 2021; Tregubova et al., 2020), TPD needs to improve teachers' ability of designing assessment tailored to their students.

The teachers in this study reported that they feel they have wide pedagogical knowledge, but much less control of technological tools. Learning a variety of digital tools and applying them in teaching during the second RT period was found as the most significant factor in the contribution of TPD in this, as well as in previous studies (Al-Naabi et al., 2021; Avidov-Ungar et al., 2020). Importantly, this **lack of technological knowledge probably also led to a setback in teachers' pedagogical methods**. For instance, according to this study and previous research, many teachers returned to traditional teaching with lecturing and demonstrating, even though using the online system (Pires, 2021). However, especially during the second RT period, teachers claimed that their familiarity with various digital tools helped them connect the familiar pedagogy with innovative technology and thus, as presented in previous studies, helped them preserve and improve distance-learning processes (Rodríguez-Muñiz et al., 2021; Shamir-Inbal & Blau, 2021). A major challenge for professional development is to help teachers become better problem solvers (Mayer, 2002). The teachers in this study reported that TPD helped them find ideas for problem-solving and creating an online learning-teaching environment, one in which the teacher felt confident in his/her ability.

Furthermore, it is important to note that the needs and requirements of **teachers at different career stages** differ from one RT period to another (Avidov-Ungar & Herscu, 2020). Senior teachers faced great technological challenges during the first RT period. These teachers had extensive pedagogical knowledge and were personally motivated to learn, but it was necessary to ensure an optimal adjustment of TPD suited to their needs. Senior teachers were required to face great challenges during the first RT period in order to instantly operate basic digital tools, such as *Zoom*. Therefore, their familiarity with technological tools was the most significant contribution to their professional knowledge. In contrast, middle career-stage teachers looked more for ideas to solve problems and how to acquire knowledge relevant to their teaching than the other career stage groups. Thus, in designing TPD, it is especially necessary to adapt the characteristics of the TPD training to the specific needs of each career-stage group (Avidov-Ungar & Herscu, 2020).

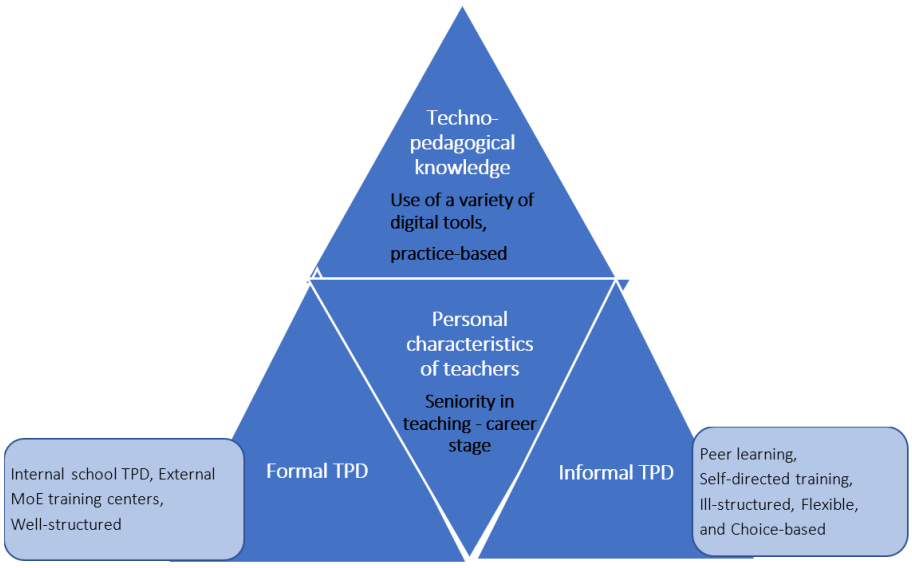

Fig. 2 Characteristics of formal and informal TPD for hybrid/remote teaching

Figure 2 presents the parameters which need to be considered in planning formal and informal TPD processes for RT or for hybrid teaching settings, taking into consideration teachers' characteristics, such as career stage and previous techno-pedagogical knowledge, as found in this study.

Limitations and future directions

This study utilized a mixed-method research design, focusing on qualitative thematic analysis of teachers' self-reports. While this approach provided deep insights, it inherently limits the generalizability of the findings. Future studies could enhance validity by triangulating self-report data from interviews with direct classroom observations.

Although distributing surveys to a nationally representative sample was considered, the chosen methodology allowed for a detailed understanding of specific themes and patterns. Future research might include large-scale quantitative studies to complement these findings and allow for broader generalization.

This study concentrated on elementary school teachers to maintain a focused scope, given resource constraints. Future research should include a more diverse sample, incorporating both elementary and secondary educators, to provide a more comprehensive perspective.

Finally, while this study focused on remote teaching during emergency situations, future studies could explore formal and informal professional development across different career stages and compare remote teaching during crises with routine learning environments.

Conclusions and implications

The findings of this study highlight the need to strengthen teachers' professional development in both formal and informal training in order to promote optimal pedagogical processes in integrated digital tools into RT, as well as in routine teaching. RT required the same important teaching skills which have relevance to routine times, for teachers and students alike (Al-Naabi et al., 2021). During the RT periods, teachers were exposed to and learned how to use a variety of technological tools (Shamir-Inbal & Blau, 2021). In order to achieve readiness and ability of staff for technology use, both routinely and in times of emergency, it is important to ensure that professional development enables the acquisition of applied knowledge, so that teachers will be able to use this knowledge optimally in their teaching (Shamir-Inbal & Blau, 2021). Moreover, TPD should focus on the individual needs of the teachers and enable system flexibility and choice, as we suggested in the model presented in Figure 2. Peer learning and learning through social interactions are significant contributions to teacher development processes (Al-Naabi et al., 2021; Shamir-Inbal & Blau, 2022). Considering TPD, social learning substantiates many professional development activities, such as learning communities, mentorship, peer review, collaborative learning, and social networking. It seems that learning from other teachers is one of the powerful TPD approaches.

Abbreviations

TPD: Teacher Professional Development; RT: Remote Teaching; MoE: Ministry of Education.

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Authors' contributions

Tamar Shamir-Inbal: Conceptualization, funding acquisition, methodology, writing the original draft.

Orit Avidov-Ungar: Conceptualization, funding acquisition, investigation, methodology, supervision, project administration, writing – review and editing.

Shlomit Hadad: Data curation, formal analysis, writing parts of the original draft, writing – review and editing.

Ina Blau: Conceptualization, funding acquisition, methodology, writing – review and editing.

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Availability of data and materials
The data can be obtained from the corresponding author upon request.

Declarations

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