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Examining the Relationship between Contextual Factors and TPACK Development in an Online Teacher Professional Development Program in the Caribbean

Lance Armistead

Jonathan Cohen
Georgia State University

Jennifer Darling-Aduana
Georgia State University

Brendan Calandra
Georgia State University

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Abstract

Although research exists on features of effective professional development surrounding Technological Pedagogical Content Knowledge (TPACK), relatively few studies have examined the relationship of context to the acquisition of TPACK. Despite this framework's dominance in the literature, the role that contextual factors play in the development of TPACK is not well understood. This study employed a sequential mixed methods investigation of the relationship between contextual factors and TPACK in a group of teachers from the Organization of Eastern Caribbean States during an online teacher professional development program designed to enhance their skills relating to teaching and learning online. Results demonstrated that several factors, including collaboration with colleagues, level of autonomy in teaching, and access to technology, were all associated with differences in levels of TPACK among participants and related to contextual factors such as urbanicity, age of students/parent involvement, and school/school system culture.

Keywords: TPACK, Context, Teacher Professional Development, Caribbean Context

Online learning has been steadily increasing over the past two decades, with millions of students taking online courses around the world (Palvia et al., 2018). Although some skills from face-to-face teaching can be transferred to an online setting, many competencies for online teaching are unique to the online environment (Barbour, et al., 2013). For example, facilitating interaction in an online setting looks different than in an in-person classroom (Pulham & Graham, 2018). The technological pedagogical content knowledge (TPACK; Mishra & Koehler, 2006) framework describes skills needed to teach with technology and thus is a useful lens through which to view the skills for teaching online. This framework describes the complex interactions between three bodies of knowledge required to effectively integrate technology into teaching practice—technological (TK), pedagogical (PK), and content (CK) knowledge—and the intersections of each domain. TPACK is an extension of Schulman's (1986) pedagogical content knowledge (PCK) framework. In the PCK framework, CK describes a teacher's understanding of the subject matter they are teaching, and PK is the methods that the teacher employs to make that content accessible to students. However, CK and PK are not effective in isolation. Although some pedagogical methods can be applied across content areas, a teacher must also tailor pedagogy to the specific content being taught and learner needs. This integrated knowledge is known as PCK. In order to account for the growing importance of technology in education, Mishra and Koehler (2006) expanded upon Schulman's PCK framework by adding a technological knowledge (TK) domain. The resulting framework is TPACK.

Context is a critical factor that influences teachers' TPACK. Mishra and Koehler (2006) described context as including the subject matter, grade level, student characteristics, and technologies available to teachers and students. Kelly (2008) defined contexts in a similar manner, consisting of the learning environment and school characteristics, both of which are

constantly evolving. Kelly (2007) argued that teachers must fully understand and adapt to the unique context in which they teach in order to most effectively leverage their TPACK. In contrast to these early conceptualizations of context within TPACK which were relatively vague, Porras-Hernandez and Salinas-Amescua (2013) developed a more comprehensive framework that includes two types of actors (teachers and students) and a scope encompassing three levels (macro, meso, and micro). In this framework, contextual factors relating to students include the value they assign to education and their previous knowledge, attitudes, beliefs, and interests. Factors relating to teachers consist of their attitudes, self-efficacy, pedagogical beliefs, and expectancies of success. These actors exist across three levels of scope. The macro level includes global and national factors such as technological developments, government policies, economic conditions. Next, the meso level describes the local community and school, including societal, cultural, political, and economic conditions. Finally, the micro level is comprised of in-class conditions like access to resources and the beliefs and goals of teachers and students.

Although context is a critical component of TPACK (Koehler & Mishra, 2009) it is complex and not well understood by researchers (Brianza et al., 2022; Kelly, 2010). Furthermore, context is often overlooked by researchers, as it is not included in the description, explanation, or operationalization of TPACK in the majority of empirical studies on TPACK (Rosenberg & Koehler, 2015). Further research is needed to better understand how different contexts interact with teachers' TPACK. This is especially important because understanding how changes in context affect different domains of TPACK can help practitioners to develop the skills that they need to teach with technology (Swallow & Olofson, 2017).

The Caribbean Context and Rationale for the Study

Although online learning takes place in many countries around the world, less is known about online learning in an international context because the majority of research of online learning has focused on the United States (Barbour, 2018a). Of the research that was carried out in an international context, most has taken place in Canada, Europe, Asia, South Africa, Australia, and New Zealand (Barbour, 2018b). Much less research exists on online learning in developing countries in Latin America and the Caribbean. This may be because online learning in the area is not as widespread as in other parts of the world (UNESCO, 2020). The issue is particularly challenging in the Caribbean because of a lack of access to the internet and devices needed for online learning (Bleeker & Crowder, 2021). However, initiatives exist to broaden access to online learning in the region. Some aim to improve internet connectivity in the region, while other programs have been designed to train teachers for teaching online (Bleeker & Crowder, 2021). One such teacher training program was recently enacted across the nine English-speaking member states of the Organisation of Eastern Caribbean States (OECS).

The OECS is an intergovernmental organization of 11 member states that have formed economic, political, and educational unions. There are seven protocol members, which enjoy full membership: Antigua and Barbuda, Commonwealth of Dominica, Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia, and Saint Vincent and The Grenadines, and four associate members which enjoy many of the same membership privileges: Anguilla, British Virgin Islands, Martinique, and Guadeloupe. French-speaking Martinique and Guadeloupe are territories of France and did not participate in the training program that is the focus of the present study. The nine members that did participate are very diverse. For example, they vary greatly in the size of their population, ranging from Monserrat with 5,387 inhabitants (Central Intelligence Agency

[CIA], 2022c) to Saint Lucia with 167,637 (CIA, 2022d). Additionally, although they are all classified by the United Nations as "small island developing states" (2021, p. 130) their economies vary greatly. Member countries' gross domestic products per capita range from that of Saint Vincent and the Grenadines of approximately $12,100 (CIA, 2022e) to that of the British Virgin Islands of $34,000 (CIA, 2022b). As a point of comparison, the United States has a gross domestic product per capita of approximately $60,000 (CIA, 2022f). The percentage of the population that uses the internet also varies greatly, ranging from 22% in St. Vincent and the Grenadines (CIA, 2022e) to 82% in Anguilla (CIA, 2022a). As a point of reference, 87% percent of people in the United States access the internet (CIA, 2022f). This diversity of contextual factors in this environment makes the English-speaking states in the OECS a unique research setting from which to study how contexts shape teachers' TPACK development.

In addition to the diversity among such macro-level contextual factors, there are meso- and micro-level factors that make this a particularly interesting study location. Thompson et al. (2011) describe K-12 education in the English-speaking Caribbean as struggling to overcome challenges anchored in its colonial past. Such challenges include teacher-centered classrooms and the belief that students learn best when dealt with harshly. Much of primary education focuses on drilling facts and skills for high-stakes exams that determine students' options for competitive secondary school placement. In addition, Thompson et al. (2011) explain that it can be difficult to attract and retain high quality teachers. Some teachers begin teaching immediately after finishing secondary school without attending postsecondary institutions or receiving any training for teaching. Some of these teachers teach for years before receiving any such training, entrenching ineffective instructional practices that may be difficult for them to change.

Attempts to reform teacher practice and encourage more constructivist-oriented approaches have been largely unsuccessful, with teacher-centered methods continuing to prevail (Leacock & Warrican, 2020). This has also been the case with technology integration into education in the region. Governments and nongovernmental agencies have invested money in technology for school systems, teachers, and students, though the limited amount of training that accompanied these investments focused only on TK, leaving teachers unsure of how to incorporate the technology into the teaching (Leacock & Warrican, 2012; Maharaj-Sharma et al., 2017). Further complicating the issue is a "systemic 'anti-technology in teaching and learning' movement" that hinders progress in teacher adoption of technology use in the classroom (Leacock & Warrican, 2020, p. 577). In fact, many teachers view technology as a distraction from high-stakes exam preparation rather than a tool for learning (Veira et al., 2014). On the occasions that technology is used, it tends to be in a superficial manner that is tightly controlled by the teacher (Leacock & Warrican, 2012).

The Eastern Caribbean Joint Board of Teacher Education (ECJBTE) has recognized the need to enhance online teaching abilities for educators in the Caribbean. The disruptions in learning due to the COVID-19 pandemic were not the first time that Caribbean educators were forced to adjust to interruptions in face-to-face learning, as the Caribbean frequently suffers natural disasters such as hurricanes, floods, and earthquakes (Organisation of Eastern Caribbean States, 2020). The Effective Pedagogy for Distributed Teaching and Learning (EPDTL) online professional development program was created to provide teachers with opportunities to acquire these online teaching skills. The underlying theoretical framework used for the EPDTL program was distributed teaching and learning (DTL), which is a teaching model that allows teachers and students to be in different geographical locations while having the content and materials

accessible at any time, and from anywhere to allow for student learning to occur regardless of time and place (Fletcher et al., 2007). Fletcher et al. describe DTL as usually taking place online, though other means such as mail, television, and radio are other ways that DTL can be used when online education is not possible. The authors were asked to observe during this program and collect data on its effectiveness. This paper reports on findings related to a set of contextual factors based on Porras-Hernandez and Salinas-Amescua's (2013) framework.

Purpose

Using an explanatory sequential mixed-method design (Creswell & Clark, 2017; DeCuir-Gunby & Schutz, 2017), we examined the extent to which macro-, meso-, and micro-level contextual factors interacted with teachers' TPACK development during the EPDTL program. Specifically, we examined the following research questions: (1) To what extent did initial TPACK vary along macro, meso, and micro contextual factors? (2) By how much did teachers demonstrate differential TPACK development along those same dimensions? And lastly, (3) Which characteristics of the professional development program appeared to support TPACK development, overall and for teachers in environments with specific contextual factors?

Methods

Phase one of this study included quantitative data collection and analysis. Phase two involved qualitative data collection and analysis with the goal of interpreting and providing clarification on the results from the first phase. The results from the first phase of research informed the data collection and analysis procedures in the second phase. All findings were then examined to provide a holistic view of how context may have interacted with participants' TPACK before and after the training program.

Learning Environment

The EPDTL program was developed by a joint venture between OECS Commission, ECJBTE, and the University of the West Indies. Program directors included university faculty members in education- and science-related fields. They developed the program and assigned participants to groups of approximately 20 teachers with whom they learned throughout the course. These teachers were mostly grouped with other teachers from the same country, though in some cases they were grouped with teachers from other countries as needed to balance group numbers. Each group was assigned an e-tutor. These e-tutors were educators, including university faculty members and doctoral students in fields such as educational policy and educational leadership. Modules and activities were self-paced, and e-tutors guided participants by sending them messages regarding their progress, answering questions about content, and assisting them with technical issues. They also assessed and provided feedback on the portfolio artifacts that they created in each module. Participants had the option of attending weekly live virtual sessions hosted by e-tutors for help on content. One such session, for example, was on using technological tools, including Nearpod. They also had the option to request a live help session with their e-tutor at any point throughout the course.

The course began with a brief orientation module and then consisted of five modules with the expectation that teachers would complete one module per week. Each module was broken into four or five units, and each unit consisted of several tasks. The structure of the course required participants to complete tasks, units, and modules in a specific order, with the completion of one step granting access to the next step.

Tasks contained instructional videos, some of which were created specifically for the course by e-tutors and facilitators and others were sourced from various online sources. These

videos were generally between one and six minutes long and usually included audio of a speaker explaining a topic and visuals of supporting text and graphics. Tasks also contained readings that were a few short paragraphs in length and explained course concepts. Most of these explanations were written by program facilitators. Participants then took short self-assessment quizzes over the material covered. Participants immediately received feedback on their answers that stated whether the answer was correct or not and explained what the correct answer should be. Participants also completed journal entries and posted in a discussion board in each module. In the majority of cases, participants did not respond to each other's posts, though e-tutors did respond to some of the posts.

The following is an example of a task, which later became part of participants' portfolios:

> As a teacher leader in a small island developing state, you have realised that the quality of teaching and learning in your team (e.g. Grade level, subject group) has declined somewhat since the onset of COVID19, as a result of all the associated challenges, both with students and teachers. You lead a mixed team of teachers- two with more than 15 years of experience, one with 8 years and two with less than 5 years of teaching experience.
>
> You have not seen any of them in person for more than a year, but you know that they need encouragement and support with their classes, given the questions and comments you have been receiving. There is also a friend in another island, who is also a teacher leader, and who is experiencing some of the same challenges.
>
> Your Task:

Brainstorm some ideas on how you can support your team, given that you cannot yet meet face to face, and select one resource you might want to share with them to help improve the quality of instruction taking place in this distributed environment.

Remember what you have learned in terms of supporting remote teams and leadership.

Also note that your team may include teachers who are floundering in this new environment as well as a teacher leader friend who is experiencing the same problems.

You decide to share it with your fellow team leader to get some feedback, for those who are experiencing some of the same problems. Create a… document to share one of these ideas for supporting your team and why you choose the resource you selected.

Data Collection and Analysis

First Phase Data Collection

Both pre- and post-program surveys collected demographic information (i.e., country of employment, gender), professional details (i.e., level of training, grade taught, teacher and student access to technology, level of parental involvement), and responses from a self-report TPACK measurement instrument (Archambault & Crippen, 2009). See Results for analysis of these data.

The widely used Archambault and Crippen (2009) TPACK instrument was chosen for the present study because it was designed specifically to measure in-service K-12 teachers' TPACK in an online instructional setting. Content and construct validity were established for the instrument, as well as reliability of scores (Archambault & Crippen, 2009). Demographic

questions for the other two portions of the survey were developed by the authors and training program directors.

In total, 626 of the 980 (64%) participants completed the pre-program survey. Out of these survey responses received in the pre-course administration, 116 were not included for data analysis in this study because at least 15% of data was missing from them (Creswell & Guetterman, 2019). Others did not meet the inclusion criteria for the study, as four were excluded because the respondents were administrators rather than teachers, and one was excluded because the respondent had never taught before and was not currently teaching. The remaining 505 responses were used in the data analysis.

Notably, 167 participants completed the post-survey, with 158 participants completing both the pre- and post-surveys. Despite this rate of attrition, we observed only a few statistically significant differences between participants who completed both surveys versus those who only completed the pre-survey on contextual measures, as shown in Table 1. Specifically, teachers who reported higher teacher and student technology access were significantly more likely to complete the post survey, which likely indicates higher rates of program completion.

We operationalized macro measures as factors likely to be associated with technology access and use at the country level. The vast majority of participants who responded to both surveys resided in an independent (versus commonwealth) country that were predominantly rural in urbanicity according to the CIA. Additionally, over three-fourths of participants in the sample resided in countries identified as middle-upper (versus high) income by the World Bank.

At the meso level, autonomy was operationalized as the amount of control the teacher participants could exercise over what they taught online, how to teach the content, and the technologies they were able to use. Peer collaboration was operationalized as the frequency at

which teacher participants could work with colleagues to develop online learning content. Parent involvement was operationalized as the teacher participants' perceptions of the amount that parents were involved in students' online schooling. Similarly, the measures of teacher and student technology access was determined by the teacher participants' perceptions of the level of access they and their students had to learn successfully at a distance.

Table 1

Macro, Meso, and Micro Contextual Measures by Sample

	All Pre-Data	Pre & Post Data	T-test
	Macro		
High income	0.186 (0.390)	0.165 (0.372)	0.840
Independent country	0.968 (0.175)	0.987 (0.112)	-1.648
Predominantly urban	0.202 (0.402)	0.196 (0.398)	0.218
Mixed urbanicity	0.137 (0.344)	0.095 (0.294)	1.843
Predominantly rural	0.661 (0.474)	0.709 (0.456)	-1.522
	Meso		
Autonomy in online content (1-5)	3.032 (1.201)	3.019 (1.120)	0.160
Autonomy in online pedagogy (1-5)	3.739 (0.934)	3.829 (0.918)	-1.471
Autonomy in online technologies (1-5)	3.374 (1.071)	3.456 (1.062)	-1.153
Peer collaboration (1-5)	2.885	2.867	0.2287

	(1.196)	(1.272)	
Parent involvement (1-5)	2.770	2.785	-0.248
	(0.888)	(0.912)	
	Micro		
Teacher technology access (1-5)	2.693	2.835	-2.177*
	(0.995)	(1.002)	
Student technology access (1-5)	2.156	2.291	-2.367*
	(0.867)	(0.919)	
Early primary grades (K-Gr1)	0.402	0.373	0.431
	(0.491)	(0.485)	
Middle primary grades (Gr2-5)	0.661	0.665	-0.848
	(0.474)	(0.474)	
Upper primary grade (Gr6)	0.293	0.272	0.343
	(0.456)	(0.446)	
Teaching status: untrained	0.255	0.228	0.639
	(0.437)	(0.421)	
Teaching status: trained, no graduate degree	0.442	0.424	0.046
	(0.497)	(0.496)	
Teaching status: trained, graduate degree	0.303	0.348	-1.490
	(0.460)	(0.478)	
Teacher experience (years)	12.905	14.006	-1.838
	(9.108)	(9.215)	
N	505	158	

Standard deviations in parentheses, * $p < .05$

First Phase Data Analysis

The TPACK self-assessment instrument (Archambault & Crippen, 2009) demonstrated an acceptable level of internal reliability in the pre-course (Table 2) and post-course (Table 3)

administrations in the present study, with Cronbach's alphas between .78 and .96 (Gall et al., 2003).

Table 2

Reliability Analysis for TPACK Score and Subscores from Archambault and Crippen (2009) Pre-Course Survey

Domain	Number of Items	Number of Responses	*M*	*SD*	Cronbach's Alpha
PK	3	503	3.22	.755	.780
C	3	500	3.34	.752	.734
TK	3	504	2.42	1.04	.884
TPACK	24	479	3.01	.680	.952

Table 3

Reliability Analysis for TPACK Score and Subscores from Archambault and Crippen (2009) Post-Course Survey

Domain	Number of Items	Number of Responses	*M*	*SD*	Cronbach's Alpha
PK	3	174	3.42	.789	.817
CK	3	175	3.50	.789	.762
TK	3	177	2.69	.999	.877
TPACK	24	166	3.22	.671	.957

Following data cleaning and assumptions testing, we estimated OLS regression models to examine the association between contextual factors and initial (pre-professional development) TPACK. Then, we used growth models to examine teachers' demonstrated differential TPACK development along the same contextual measures following the professional development program.

Second Phase Data Collection

The second phase of data collection employed interviews to answer the third research question (i.e., which characteristics of the professional development program appeared to support

TPACK development, overall and for teachers in environments with specific contextual factors?). The interview topics and questions were informed by the results of the first phase analysis.

Interview participants were recruited through an additional question included at the end of the post-program quantitative survey. These potential participants were emailed once every 2 weeks over a 6-week period to confirm and arrange participation. The goal in recruiting was to interview participants that represent a diversity of contexts, including years of experience, grade levels, countries, and self-reported TPACK levels. The six participants who were interviewed were from four different countries and reported a wide range of overall TPACK scores ranging from 1.88 to 4.88 (on a scale of 1-5). Each had taught a different grade level online. Their teaching experience ranged from three to 31 years. No men indicated that they would be willing to participate in a follow-up interview in their post-course survey, so all participants were women. The interviews took place until data saturation was met, which occurred when the same information began to be encountered repeatedly and no new perspectives were expected to come from further data collection (Sandelowski, 2008). Interviews were conducted virtually and were semi-structured to allow for the exploration of any unanticipated themes that arose over the course of the interview. Interviews were recorded and transcribed for data analysis.

Second Phase Data Analysis

Data from the interviews were analyzed by one of the researchers with thematic analysis through the lens of TPACK (Mishra & Koehler, 2006), Porras-Hernandez and Salinas-Amescua's (2013) framework for context in TPACK, and Desimone's (2009) framework for effective professional development. Braun and Clarke's (2006) six-step process for thematic analysis was employed. In the first stage of familiarization, data from the interviews were

transcribed and analyzed, and notes were made of initial ideas and impressions. In the next step, initial codes were generated. Structural coding (Saldaña, 2016) was utilized to categorize chunks of data in a deductive manner. The different domains of TPACK, along with the macro, meso, and micro levels with teacher and student factors of context in TPACK (Porras-Hernandez & Salinas-Amescua, 2013) were used as *a priori* coding categories along with content focus, active learning, coherence, collective participation, and duration to explore how elements of a training program could affect TPACK development (Desimone, 2009). Open coding (Corbin & Strauss, 2015) was also used throughout the data analysis process to generate additional codes to represent any additional themes relating to either research question that were found in the data.

After data were coded preliminarily, Braun and Clarke's (2006) third step of searching for themes began. Pattern coding (Saldaña, 2016) took place to sort initial codes into potential themes and collate codes within those themes to form subthemes. Themes were reviewed and refined in the fourth step, which entailed eliminating candidate themes for which there was not enough evidence to support them, collapsing what had previously seemed like separate themes into one theme, and breaking themes apart if data within them constituted more than one theme. In this step, data within each theme was analyzed to ensure that they form a coherent pattern. When they did not, the theme itself and the placement of the data within them was reevaluated. Then, the themes were evaluated in terms of how they tell the story as a whole and accurately represent the data. Next, in the fifth step, themes were defined and named. The essence of each theme was described with a concise, yet detailed analysis. Finally, reporting occurred in the sixth phase. This entailed providing compelling evidence from the data to form a "coherent, logical, non-repetitive and interesting account of the story the data tell—within and across themes" (Braun & Clarke, 2006, p. 93).

Integration of Qualitative and Quantitative Findings

Coxon (2005) argues that both quantitative measures and qualitative descriptions are necessary to fully understand the essence of a phenomenon. In mixed methods research, qualitative and quantitative methods are integrated throughout the research process (Teddlie & Tashakkori, 2009). Accordingly, qualitative and quantitative results were brought into dialogue during the analysis and interpretation of results. As demonstrated in the results, qualitative findings were examined alongside quantitative findings to provide a holistic view of how context may have interacted with teachers' TPACK before and after a training program and how different aspects of the program may have impacted teachers' TPACK development.

Results

Initial TPACK by Contextual Factors

We first estimated regression analyses to examine the association between macro, meso, and micro contextual factors and initial (pre-professional development) TPACK, as shown in Table 4. We estimated separate equations to predict overall TPACK as well as each individual component (PK, CK, and TK). At the macro level, country-level urbanicity was significantly associated with participants' initial PK and CK but not overall TPACK. We observed no association between country-level income or governmental type and TPACK. At the meso level, autonomy in online pedagogy was strongly associated with overall TPACK as well as PK, CK, and TK individually. Respondent ratings of peer collaboration were also associated with overall TPACK and CK and TK (although not PK) individually. However, we did not identify a statistically significant relationship between TPACK and other meso-level contextual factors such as autonomy in online content, autonomy in online technologies, or parent involvement.

In contrast, we observed several statistically significant associations between TPACK and the micro-level contextual factors examined. In particular (in order of magnitude), teaching at the middle grade level (β=0.296), teacher technology access (β=0.196, on a 5-point scale), student technology access (β=0.119), and number of years teaching (β=-.013) were all significantly associated with overall TPACK at one or more individual TPACK components at the 0.05 significance level. These associations may indicate that teachers of older students had more prior experience or support enacting TPACK prior to the training. Additionally, it makes sense that teachers in schools with higher rates of teacher and student technology access would have more opportunities to experiment with and build mastery with technology use in the classroom. Lastly, the negative association between years teaching and TPACK may be a result of younger teachers receiving more explicit training on technology use in the classroom and/or have more native familiarity with and mastery of technology in general.

Table 4

Initial TPACK by Macro, Meso, and Micro Contextual Measures

	PK	CK	TK	TPACK
	Macro			
High income	0.115	0.043	0.149	0.042
	(0.093)	(0.092)	(0.123)	(0.080)
Independent country	-0.160	-0.107	-0.243	-0.159
	(0.205)	(0.201)	(0.270)	(0.175)
Predominantly urban	0.169	0.245**	-0.039	0.134
	(0.113)	(0.111)	(0.149)	(0.096)
Predominantly rural	0.168*	0.224**	-0.102	0.118
	(0.100)	(0.098)	(0.132)	(0.085)
	Meso			
Autonomy in online content (1-5)	-0.008	-0.004	-0.022	0.004
	(0.028)	(0.027)	(0.036)	(0.024)

Autonomy in online pedagogy (1-5)	0.119***	0.128***	0.101*	0.084**
	(0.039)	(0.038)	(0.051)	(0.033)
Autonomy in online technologies (1-5)	0.022	0.021	0.028	0.026
	(0.034)	(0.033)	(0.045)	(0.029)
Peer collaboration (1-5)	0.040	0.054**	0.101***	0.067***
	(0.027)	(0.026)	(0.035)	(0.023)
Parent involvement (1-5)	0.011	-0.017	0.056	0.016
	(0.038)	(0.037)	(0.050)	(0.032)
	Micro			
Teacher technology access (1-5)	0.161***	0.148***	0.266***	0.196***
	(0.037)	(0.036)	(0.048)	(0.031)
Student technology access (1-5)	0.123***	0.141***	0.054	0.119***
	(0.045)	(0.044)	(0.059)	(0.038)
Middle primary grades (Gr2-5)	0.069	0.026	0.166*	0.109*
	(0.066)	(0.065)	(0.087)	(0.056)
Upper primary grade (Gr6)	0.239***	0.228***	0.495***	0.296***
	(0.069)	(0.068)	(0.091)	(0.059)
Teaching status: trained, no graduate degree	0.128	0.090	-0.169	0.054
	(0.086)	(0.084)	(0.113)	(0.073)
Teaching status: trained, graduate degree	0.211**	0.237**	-0.143	0.171*
	(0.103)	(0.101)	(0.136)	(0.088)
Teacher experience (years)	0.001	0.004	-0.031***	-0.013***
	(0.004)	(0.004)	(0.006)	(0.004)
Constant	1.628***	1.641***	1.277***	1.544***
	(0.295)	(0.290)	(0.389)	(0.252)
Observations	505	505	505	505
Adjusted R-squared	0.164	0.186	0.238	0.252

Standard errors in parentheses, * p<0.10, ** p<0.05, ***p<0.01

Differential TPACK Development

Next, we examined the extent to which teachers demonstrate differential TPACK development along the same macro, meso, and micro contextual measures after participating in the professional development program, as shown in Table 5. We accomplished this using growth models that controlled for participants' baseline scores and included the teachers' change in TPACK between the post- and pre-intervention period as the dependent variable. As expected, initial baseline scores were negatively associated with change in TPACK, given that teachers with higher initial TPACK scores were limited in their measured growth through a measure-based ceiling effect. Interestingly, none of the contextual measures were significantly associated with the change in TPACK score at the 0.05 level, although the constant indicates that all else held constant the modal increase in TPACK score was approaching significance.

When examining associations with individual TPACK components, however, a few macro- and meso-level contextual factors appeared significantly associated. Specifically, teachers in countries identified as predominantly urban were significantly more likely to improve in CK (β=0.448), while teachers in countries identified as predominantly rural were significantly less likely to improve in TK (β=-0.557). Additionally, for each one-point increase (on a five-point scale) in teacher reported peer collaboration, the typical teacher increased their TK by 0.115 points (on a five-point scale).

Table 5

Change in TPACK by Macro, Meso, and Micro Contextual Measures

	PK	CK	TK	TPACK
Baseline Score	-0.521***	-0.428***	-0.427***	-0.397***
	(0.086)	(0.084)	(0.066)	(0.076)

	Macro			
High income	-0.250	-0.194	0.170	-0.171
	(0.161)	(0.159)	(0.173)	(0.129)
Independent country	0.074	0.690	0.121	0.205
	(0.526)	(0.517)	(0.557)	(0.414)
Predominantly urban	-0.029	0.448**	-0.308	0.231
	(0.224)	(0.220)	(0.240)	(0.178)
Predominantly rural	-0.166	0.044	-0.557**	-0.027
	(0.201)	(0.197)	(0.215)	(0.159)
	Meso			
Autonomy in online content (1-5)	-0.074	-0.042	0.029	-0.044
	(0.051)	(0.050)	(0.055)	(0.040)
Autonomy in online pedagogy (1-5)	0.067	0.040	0.043	0.027
	(0.068)	(0.067)	(0.072)	(0.054)
Autonomy in online technologies (1-5)	0.021	-0.046	-0.045	-0.019
	(0.059)	(0.058)	(0.063)	(0.047)
Peer collaboration (1-5)	-0.022	0.019	0.115**	0.017
	(0.045)	(0.044)	(0.048)	(0.036)
Parent involvement (1-5)	0.010	-0.055	-0.080	-0.041
	(0.067)	(0.066)	(0.072)	(0.053)
	Micro			
Teacher technology access (1-5)	0.097	0.089	0.077	0.054
	(0.067)	(0.066)	(0.072)	(0.055)
Student technology access (1-5)	0.037	-0.040	0.074	0.020
	(0.078)	(0.077)	(0.081)	(0.061)
Middle primary grades (Gr2-5)	0.097	0.043	0.044	0.055
	(0.116)	(0.114)	(0.125)	(0.092)
Upper primary grade (Gr6)	0.086	-0.002	0.133	0.061
	(0.125)	(0.121)	(0.137)	(0.100)

Teaching status: trained, no graduate degree	-0.030	-0.012	0.122	-0.073
	(0.159)	(0.156)	(0.170)	(0.126)
Teaching status: trained, graduate degree	0.219	0.180	0.143	0.037
	(0.188)	(0.185)	(0.198)	(0.148)
Teacher experience (years)	-0.005	-0.001	-0.009	0.001
	(0.008)	(0.008)	(0.009)	(0.006)
Constant	1.409*	0.771	0.957	1.075*
	(0.724)	(0.707)	(0.743)	(0.569)
Observations	158	158	158	158
Adjusted R-squared	0.176	0.173	0.212	0.137

Standard errors in parentheses, * p<0.10, ** p<0.05, ***p<0.01

Effective Professional Development Characteristics

Building on the analysis we conducted from the survey data, we used interviews to examine which characteristics of the professional development program appeared to support TPACK development, overall and for teachers in environments with specific contextual factors. Major themes developed from the data were based on Desimone's (2009) program duration and structure, active learning, collective participation, content focus, and coherence. These themes reveal aspects of the program that participants believed enhanced their ability to develop the skills to teach online as well as obstacles that presented challenges in developing TPACK or in completing the program. Most relevant to the relationship between context and TPACK development, we focus below on the roles that program duration and structure, collective participation, and coherence played in teachers' TPACK development.

Program Duration and Structure

The 11-week training course began with a 1-week orientation module and then included five 2-week content modules. The modules could only be completed sequentially, as access to

later modules was only granted after completion of the previous module. One feature of the training program that affected teacher motivation, quality of the work they produced, and even program completion was its use of deadlines. The expectation was that teachers would complete each module within 2 weeks and then move on to the next. This was not always commensurate with the realities of the teachers' schedules. Although e-tutors generally did allow deadline extensions, it appears that this may not have been widely known. One participant explained that colleagues she knew who took the course dropped out because they had missed a deadline or were worried that they could not meet an upcoming deadline. Another teacher explained that she felt so rushed to turn in an assignment by the due date that she rushed through rather than taking the time to fully explore and learn how to effectively use the technology being presented.

A major challenge that some of them encountered in meeting program deadlines was finding time to complete coursework and continue to fulfill their other commitments. Participants estimated that they spent between 2 to 5 hours a week completing course requirements. All of them were teaching full time, so they had to carve out moments to complete these requirements in the evenings, on weekends, or over holiday breaks. One participant was even simultaneously enrolled in a university degree program while taking the course and struggled to find time to work on both. For these participants, the asynchronous self-paced nature of the course was essential in allowing them to fit course requirements into their busy schedules. Finally, another participant shared experiences of some of her friends who began the course but did not finish. She explained that their husbands were not supportive of the time they would need away from home, expecting dinner to be served on time and their normal level of attention to their children to be maintained. Her friends felt that they could not fulfill these duties and the commitments necessary to complete the program.

Collective Participation

For some teachers, colleagues enrolled in the course were an essential source of motivation and assistance in completing course requirements. Participants described being on the giving and receiving end of such support. For example, while some relied only on program e-tutors for additional support, others sought additional instruction from their colleagues. This support included sharing completed work for colleagues to use as an example from which to model their own work, providing technical support over email or phone, and even visiting colleagues in their homes to guide them through how to complete an assignment. Furthermore, participants reported giving and receiving encouragement from their peers: "I worked with them every step of the way. I would say, 'I haven't seen you submit that. Come look, mine's finished. Let's do that and let me do that.' And I was there encouraging them." It is clear that collective participation played an important role in the successful development of teachers' TPACK in the program.

Coherence

The final theme is the degree to which the training program aligned with the realities of participants' contexts in which they teach, particularly with access to resources. Given that many schools and teachers lack access to funds for educational programs and subscriptions, participants found the training program's emphasis on free resources to be beneficial. For example, four teachers found Nearpod to be particularly useful, as the free version of the service offers access to thousands of lessons and activities. As one explained:

> And Nearpod, I'd never heard of Nearpod before, never experienced it until I had this course. You know, I like the fact that it's free. As teachers, we always like the fact that something is free. And you know, it was easier to use than I thought and very much self-

> paced, you know. Lots of customizable lessons. So, this course provided a whole lot of support for us as teachers that we may not have necessarily gotten.

Kahoot was also frequently praised by interviewees, and one teacher mentioned frequently using OER Commons, a digital library with thousands of free educational resources open to the public.

Although the training program was able to help teachers with their lack of access to educational programs, it was not able to increase their access to the high quality devices that would be necessary to learn about those programs. Not having access to a quality device on which to complete the course requirements profoundly affected two participants' participation in the program. Their devices did not have sufficient computing power or capacity to complete tasks or use the applications that were taught in the program. Although one participant expressed gratitude that the ministry of education of her country provided her with a Chromebook, she explained that it was not adequate for her needs: "There are certain features you just couldn't get done on the Chromebook." She owned another computer that she also tried to use when her Chromebook could not complete a task, but it was outdated and did not perform well either. She put forth her best effort to fully explore the features of the programs to the extent that her devices would allow, but she felt that she was not able to take full advantage of the training. In fact, she experienced so many complications and delays due to her computer's limited capabilities during the course that she was shocked that the computer was eventually capable of completing and submitting her online portfolio: "That was God. I believe in God… I don't know how the computer was able to solve that, but it was able to submit. Praise God."

Another participant encountered difficulties in accessing a device regularly, as her entire household shared just one computer. This prevented her from fully exploring the tools the training program was teaching:

> I have one laptop in the house. It's not even working well these days, and my daughter had to be using it during the day, so I was using my iPad. That's what I was using. So it was a bit challenging for me when you don't have the proper device. You don't have the resources. It's hard for you to use the tools that they mention.

Spending time watching the frozen screen of an outdated and underpowered device, waiting for shared devices to become available, or trying to find alternative ways to complete course assignments increased the amount of time required for some participants to complete program requirements. Combined with obstacles such other commitments competing for time, a heavy course workload, and what some believed to be an overemphasis on theory, an inadequate device was an unwelcome and debilitating barrier to course completion.

Discussion and Implications

Using an explanatory sequential mixed methods approach, this study first examined results from a survey completed by primary school teachers in nine Caribbean countries who participated in an 11-week training program for online teaching both before starting the program (N = 505) and after program completion (N = 177). Quantitative analysis found that many factors, including colleague collaboration, access to technology, and level of autonomy in teaching were associated with differences in TPACK scores and subscores. Qualitative data collected through interviews with participating teachers provided context for these findings by exploring how and why some of these phenomena occurred.

Country-level urbanicity was significantly associated with participants' initial PK and CK but not overall TPACK. Following the course, participants from more urbanized countries were more likely to improve in CK. Participants from the more rural countries were less likely to improve in TK, which perhaps is not surprising given the issues related to technology access that

surfaced through both the survey and the interviews. If teachers who work in primarily rural countries struggled with technology access, then improvement of technological knowledge would likely suffer.

Initial survey results revealed statistically significant associations between autonomy in online pedagogy and TPACK. Interview data illustrated many ways in which participants used their autonomy to benefit student learning. For example, freedom in technology use and online pedagogy allowed teachers to seek and employ solutions for unexpected challenges that the school or district may not have anticipated. This was effective for participants when finding alternative programs to use upon encountering technical problems with software, meeting unique student learning needs, and even discovering classroom management solutions that would eventually be implemented schoolwide. Similarly, flexibility in the online curriculum was a valuable tool for some participants, as it allowed them to better meet the needs of their students. Teachers who were not allowed such discretion described challenges they faced under the expectation that a curriculum designed for traditional in-person delivery would be implemented online, especially given that online learning was new to most students and teachers. Student learning suffered when no considerations were made for differences in online learning and teachers were expected to teach the same content at the same pace as they would usually teach in person. In contrast, teachers who were able to adjust the curriculum to be compatible with their new situation were able to evaluate which standards were the most critical and prioritize them over skills that may have been less essential. However, it is worth remembering that in this study, courses had recently and unexpectedly shifted online, which likely played a role in the fact the curriculum was not appropriate for emergency remote teaching.

A second meso-level factor related to TPACK in this study was teacher peer collaboration. Yeh et al. (2021) explain that evaluating technological tools and effectively integrating them into learning activities is a complex process that is most effectively undertaken when teachers work in teams. There is a motivational aspect to peer collaboration as well, as indicated by the participants in the interviews; in an environment which is notable for competing priorities and demands on teachers' time, peer collaboration on professional learning activities can help to ensure sustained motivation (Kolleck, 2019). However, qualitative findings in this study also revealed that teachers can face a multitude of challenges in sharing skills, evaluating options, and reflecting on practice with other educators. One such barrier was being the only person teaching a specific grade level or subject in the school. For example, a participant believed that it would be counterproductive to plan online learning with teachers who taught different lessons with different groups of students and thus only contacted others on rare occasions for brief consultations. Another barrier identified in the qualitative analysis was that some teachers only collaborated with other educators in a system in which they submit their lesson plans to supervisors who then provide one-way feedback that includes instructions on what to change. While these two models of collaboration allowed participants to learn from other educators' skills to a certain degree, they did not provide for extended and meaningful discourse, which is an essential component of effective teacher collaboration (Lefstein et al., 2020).

The micro-level association between teaching older students and higher levels of TPACK found in this study is somewhat similar to Koh et al. (2014), who found that secondary school teachers reported higher TPACK than primary school teachers, although all teachers in the present study were at the primary level (grades 1-6 in the OECS). Qualitative findings from this study also highlighted some of the challenges that teachers of early primary grades faced in

providing effective online learning experiences for their students versus teachers of older students. These challenges were reported to stem from the fact that the younger students relied more heavily on their parents to assist with online learning activities than older ones. This was perceived by participants as a potential barrier to implementing student-centered uses of technology. Additionally, the finding that parental involvement was perceived to have the potential to be detrimental for classroom discourse added further evidence that younger learners' increased reliance on parents may have complicated the online learning experience. In contrast, older elementary students were perceived as generally more independent and not requiring the same level of parental support as early elementary students. This may have presented teachers of upper grades with fewer perceived limitations when selecting and implementing appropriate technologies and activities for online learning.

The finding that both teacher and student access to technology were associated with TPACK is consistent with those in the existing TPACK literature. For example, a study on teacher technology use in several developing countries in different regions of the world found that limited access to resources can negatively affect TPACK, as teachers may resort to teacher-centered uses of technology (Dalal et al., 2017). Another example is Domina (2021), who found that children from households with less than one device per child had significantly lower learner engagement and assignment completion than those with at least one per child, even after controlling for demographic factors. Additionally, when students have greater access to technology, teachers are better able to leverage it in ways that shift technology use from teacher-centered passive learning to student-centered active learning in which students collaboratively build knowledge (Swallow & Olofson, 2017). This process could influence teachers' TPACK development as a kind of positive feedback loop; when teachers know that they can shift

technology use to more student-centered uses and they see successes from the technology integration (e.g., assignment completion, learner engagement, collaboration, active learning, knowledge building) they may be more apt to continue to develop in that direction, thus raising their TPACK.

Finally, this study found a negative correlation between years teaching and overall initial TPACK. This finding is similar to that of other studies (i.e., Koh et al., 2014; Lee & Tsai, 2010), though Cheng & Xie (2018) did not find any such relationship. This correlation was not present following the course, which has been found in other research, as initial differences in teachers' TPACK related to years of teaching experience (in addition to differences related to gender, content area, and grade level taught) were mitigated after completing a training program designed to enhance their TPACK (Cheng & Xie, 2018; Xie et al., 2017).

The results of this study suggest that collaboration, access to technology, and level of autonomy in teaching were all associated with differences in TPACK as measured by the surveys in this study and supported by data collected through interviews with selected participants. Some of these factors were also related to contextual conditions such as location, urbanicity, age of students/parent involvement, and school/school system culture. Future studies should continue to examine the influence of these factors on participants in various TPACK teacher professional development efforts and further unpack how cultural and social systems within which teachers operate might determine conditions and opportunities that influence TPACK acquisition such as levels of access to technology, ability to collaborate, and levels of teacher autonomy. Although this study was not able to account for program attrition, one should consider the differences in participants who completed the post survey versus the pre-survey sample, given that most of the survey attrition could likely be attributed to participants dropping out of the intervention. Thus,

in addition to emphasizing the fact that future endeavors should include the features listed here that were associated with increases in TPACK among completers, this supports the need to assess and provide baseline technology access for teachers and their students. Implications include the need for school leaders to better facilitate collaboration among teachers by building communities within training programs and the ever-present need for equitable access to technology in teaching and learning.

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