

# STEM Teachers' Experiences with Online Teaching During the COVID-19 Pandemic: A Canadian Context

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## Abstract

The COVID-19 pandemic necessitated the closure of K-12 schools globally, abruptly shifting to an online format or emergency remote teaching (ERT). In this chapter, the authors focus on STEM teachers' experiences with online teaching in Canada. Specifically, the authors address i) the level of support received by teachers with a focus on resources and professional development (PD), and ii) teachers' recommendations for successful online teaching in the future. A mixed-methods design was utilized, and quantitative and qualitative data were collected from teachers through an online questionnaire administered to 75 grade 1–12 STEM teachers in a large Canadian province in May–July 2020. Data analyses were guided by theoretical frameworks that entail PD, social constructivism, and communities of practice.

Results indicate that teachers faced a wide array of challenges including the fact that the support they received to effectively implement ERT did not parallel their expectations. Furthermore, the majority of teachers did not envision ERT as a positive experience for themselves nor their students. Based on their successes and challenges, participating teachers listed several recommendations to school boards, policy makers, and the government. These include clear time boundaries for teachers; centralized high-quality digital resources; quality technology for teachers and students; additional information technology and PD support; clear administrative direction; enforcing accountability measures for students; and equitable access to learning among students.

## Keywords

online teaching, K-12 education, STEM education, teacher professional development, communities of practice

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## 1 Introduction and Objectives

The COVID-19 pandemic forced the closure of most K-12 schools around the world, abruptly shifting teaching and learning to an online format. In Canada, school closures were in effect from March to June 2020, impacting 6,643,213 students (UNESCO, 2020). All provincial and territorial ministries of education instructed schools to start online/distance teaching for K-12 students. Some provinces articulated that elementary level teachers focus on mathematics and literacy, while secondary level teachers focus on literacy, math, and sciences, with a notable emphasis on science, technology, engineering and mathematics (STEM) subjects. Teachers were provided with a handful of suggestions on resources and platforms to use during online teaching.

This abrupt world-wide shift to online teaching or emergency remote teaching (ERT) (Hodges et al., 2020) was accompanied by many challenges. Documented online teaching ‘good practices’ that engage students in learner-centered approaches are considered rare. Moreover, teachers’ familiarity with integrating technology into instructional practice is limited (Reimers & Schleicher, 2020). Teachers also had to align available digital educational content with their national curricula, and at the same time cater for their students’ academic, mental health, social, and emotional needs (World Bank, 2020). The fact that online teaching was a first-of-its-kind for many educators, an exploration of teachers’ needs and practices during ERT is warranted. Thus, it is crucial to explore how STEM teachers functioned in this new teaching and learning environment. A review of the literature (e. g., Barbour, 2018; Hung, 2016; Taie et al., 2019; Tallent-Runnels et al., 2006) highlights a dearth of studies on online teaching in K-12 settings, especially in a Canadian context. Hodges et al. (2020) maintain that under normal conditions, online teaching can be evaluated using several frameworks including students’ learning, attitudes, interest, motivation, and engagement; quality of technological tools; faculty support and PD; and policy and governance matters. On the other hand, ERT evaluation needs to ask additional broader questions. Hodges and Fowler (2020) believe that teachers’ reflections can lead to better teaching practices and better preparation for similar instructional situations. Reflection can be defined as the careful examination of ideas to create new insight through ongoing cycles of expression and re-evaluation (Marshall, 2019, as cited in Hodges & Fowler, 2020). Accordingly, in this study the authors explored teachers’ reflective practices to evaluate the quality of support they received during unprecedented conditions of a pandemic.

Hence, the overall study focused on STEM teachers’ online practices during the pandemic in Canada. In this chapter, the authors focus on successes and challenges teachers encountered, including the support provided to teachers and their recommendations for improving online teaching in the future.

## 2 Literature Review

### 2.1 *Online Teaching Definition, Advantages, and Challenges*

Online teaching is the process of teaching with some, or all instructional materials delivered over the internet, with the teacher facilitating the process by structuring and sequencing the online activities (Cook & Steinert, 2013; Hoffman, 2018). Prior to the pandemic, the number of virtual schools were increasing in K-12 education. For instance, almost every state in the United States offers a version of fully online or blended education (Toppin & Toppin, 2016). Research has demonstrated many affordances associated with online teaching. First, it overcomes physical distance as a barrier to learning, allowing for more versatility and flexibility (De Paepe et al., 2018; Saadé et al., 2007; Thoms & Eryilmaz, 2014; Vivolo, 2019). From a pedagogical perspective, online teaching has a positive impact on teaching and assessment strategies (Cook & Steinert, 2013; Hung & Jeng, 2013). Teachers can incorporate effective pedagogical and instructional strategies such as games, interactive models, computer simulations and animations, and audio and video clips. Online teaching can also be adapted to the needs and lifestyles of many students, which can be beneficial for those struggling academically or who are at-risk (Toppin & Toppin, 2016). Studies have also highlighted the positive impact of internet-supported learning on students in terms of grade achievement, engagement, motivation, participation, and satisfaction (Amasha et al., 2018; Bekele & Menchaca, 2008; Dumford & Miller, 2018).

On the other hand, several obstacles and challenges face online teaching, including those associated with administration, students and teachers, pedagogy, and equity. Bolliger and Wasilik (2009) categorize the challenges as institution-related, student-related, and instructor related. Institution-related challenges entail those linked to policies, workload, time, and teacher compensation. In addition, administrative challenges include the required investments in time and money for development and maintenance, as well as the deficiency in instructional designs and valuable resources (Cook & Steinert, 2013; De Paepe et al., 2018). Toppin and Toppin (2016) also question the level of preparedness of teachers, the efficiency of their support services, and the reliability of the technology and the infrastructure required for successful online teaching. Student challenges include isolation, lack of face-to-face interaction, access to technology, and issues related to learners' motivation and engagement to learn using technology (Cook & Steinert, 2013; Davis et al., 2007; De Paepe et al., 2018; Dumford & Miller, 2018; Lao & Gonzales, 2005; Leire et al., 2016; Saadé et al., 2007; Searls, 2012; Toppin & Toppin, 2016; Zhang & Lin, 2020). On the other hand, teacher challenges include the fact that online technologies are time-consuming and require adequate technology access, equipment, and infrastructure. Moreover, from a pedagogical perspective, it can be challenging for some teachers to differentiate instruction online (Smith et al., 2016). Additionally, some teachers face challenges in nurturing higher-order thinking, student-centered teaching methods, and interaction between them, the student, and the content in online classrooms (Baran et

al., 2011). Elsewhere, the authors discuss the challenges encountered by Canadian STEM teachers, specifically in online teaching during the pandemic (DeCoito & Estaiteyeh, 2022).

## **2.2 *Emergency Remote Teaching (ERT)***

Well-planned online learning experiences in normal situations provide a robust educational ecosystem for learners. This differs from online courses offered in response to a crisis in which temporary access to instruction is provided (Hodges et al., 2020). Hodges et al. (2020) define ERT as “a temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances” (p. 6). This implies that quality online teaching requirements such as careful instructional design, planning, and development, as well as support systems are mostly absent in emergency situations such as the COVID-19 pandemic. Furthermore, teachers’ beliefs (Davis et al., 2006) and levels of self-efficacy (Bandura, 1995) are factors impacting teachers’ willingness and effectiveness in ERT contexts. Research also implies that teachers’ high self-efficacy has a very significant impact on their online teaching effectiveness (Barberà et al., 2016; Chen, 2010; Wang & Ha, 2012). Since teachers’ self-efficacy beliefs translate into quality of instruction, bringing change to teachers’ practice must start with their belief systems (Hoy et al., 2020).

As part of the larger study, DeCoito and Estaiteyeh (2022) report on STEM teachers’ general sense of dissatisfaction with and negative attitudes towards ERT during the COVID-19 pandemic in Canada. Moreover, despite few successes, teachers faced a wide array of challenges that negatively affected their views toward ERT. Teachers cited lack of readiness and lack of required technological skills, which impacted their self-efficacy. The major challenges included time constraints, digital resources and accompanying pedagogy, and student engagement. There was also an evident disconnect between teachers’ positive beliefs in their technological competence, and their evaluation of their ERT experience. This is not surprising given the lack of opportunities for teachers to engage in effective instructional design, planning, and development during crisis circumstances such as the COVID-19 pandemic. In this chapter, the authors focus on the support received by teachers and their recommendations in an attempt to further explore the reasons behind their negative attitudes toward ERT.

## **2.3 *Teachers’ Roles and Competencies in Online Teaching***

Several studies highlight the most important characteristics that exemplify successful online teachers (Dipietro et al., 2008; Pulham & Graham, 2018). Álvarez et al. (2009) collate teacher roles that are unique to teaching in virtual environments into three categories: planning and design; social; and instructive. Similarly, Zhang and Lin (2020) categorize the roles into pedagogical, managerial/logistic, and social which aims at establishing and maintaining a positive student-teacher relationship in a friendly learning

environment (Baran et al., 2011). Meanwhile, Pulham and Graham (2018) place online teaching competencies into seven categories:

1. Pedagogy which includes flexibility and personalization, student collaboration, content knowledge, discussion facilitation, student-centered learning, motivation strategies, problem-based learning, project-based learning, and student grouping.
2. Management.
3. Assessment, including timely feedback, authentic assessment, student-self assessment, formative assessment, and data use.
4. Technology which includes software and digital tools use, management, and troubleshooting.
5. Instructional design which includes curating online learning activities, diverse curriculum activities, universal design, and access.
6. Dispositions, including respect, growth mindset, and commitment to school opportunities.
7. Improvement which requires constant reflection and evaluation.

Dipietro et al. (2008) maintain that teachers need to be flexible with their time, motivate students, have good organizational skills, use student and course data to evaluate their own pedagogical strategies, and foster interaction and communication with and among students. Furthermore, Dipietro (2010) ascertains that teachers should also engage in fluid practice by guiding knowledge construction and individualizing learning; making content accessible; managing the course and maintaining academic integrity; and supporting student success by meeting their needs and structuring the content to scaffold learning. Zhang and Lin (2020) conclude that teachers should balance carefully between the time spent on managerial practices and that spent on pedagogical roles. The latter needs to be strongly emphasized to promote students' satisfaction and enhance their learning experience.

## ***2.4 Online Teaching and Teacher Training***

Acknowledging the diverse teacher roles and challenges they may encounter speaks directly to effective and focused continuous professional development (PD), including teacher education and teacher training. In a national survey in teacher education programs (all 50 states in the U.S.), Kennedy and Archambault (2012) concluded that the vast majority of the respondents did not offer online learning programs for preservice teachers. This reiterates the need to develop staff capacity to work more effectively in online environments (Bigatel et al., 2012; Davis et al., 2007). Jung (2005) highlights the importance of well-designed programs to train teachers in using information and communications technology (ICT) effectively in their teaching practice. This requires more information on

the effectiveness and cost-effectiveness of different training approaches; more research on the factors affecting students' learning process, satisfaction, and achievement; and more attention to the specific roles of ICT in modeling effective pedagogical practices.

Additionally, teacher training should be aimed at empowering online teachers, enhancing critical reflection, and incorporating technology in pedagogical inquiry (Baran et al., 2011). High-quality teacher preparation needs to focus on integrating technological, pedagogical, and content knowledge (TPACK) (Koehler & Mishra, 2009) in order to enhance teachers' competency and self-efficacy (Álvarez et al., 2009; Barnes et al., 2018; Barril, 2018; Lao & Gonzales, 2005; Recker et al., 2013; Saadé et al., 2007; Simonson et al., 2009; Tinoca & Oliveira, 2013). Teachers' technological knowledge, efficacy, motivation, and beliefs highly influence their perception of and effectiveness in terms of integrating technological tools in their practice (Barberà et al., 2016; Chen, 2010; Wang & Ha, 2012). In general, teachers need to acquire higher levels of digital literacies (Ng, 2013), which will require more training on designing appropriate curricular materials (Recker et al., 2013); instructional methods and course design (King, 2002; Simonson et al., 2009); multiple communication techniques (Fernández et al., 2017); and various essential competencies such as active/student-centered teaching, leadership, and technological competence (Bigatel et al., 2012).

Gacs et al. (2020) recommend several steps to prepare schools for online teaching, whether intentional or crisis prompted. These steps include experiencing online education from students' perspective, conducting a needs analysis to proceed accordingly, and providing training, PD, and technology support. Gacs et al. (2020) admit the difficulty of these conditions due to time constraints during crisis. Yet, even if these steps were done minimally, they would be helpful in determining the ideal outcome. Thus, it is important to explore the level of support teachers received during their pandemic-related teaching. The authors contend that setting high standards dictate high-quality actions and reflect positively on the performance of all stakeholders, even under emergency situations.

### **3 Theoretical Frameworks**

Effective STEM teaching requires teachers' proficient pedagogical content knowledge (Shulman, 1986) as well as increased self-efficacy in teaching content (Tschannen-Moran & Hoy, 2001). Similarly, when integrating technological tools in teaching, teachers need enhanced TPACK levels. The TPACK framework (Koehler & Mishra, 2009) combines the three constructs (technology, pedagogy, and subject content) both theoretically and practically, to produce the knowledge needed to successfully integrate technology into teaching. Furthermore, this complex teaching and learning environment requires unique teacher preparation and support. Thus, the theoretical frameworks include PD, social constructivism, and communities of practice. These frameworks inform the design of the



study instruments including the questionnaire, as detailed in section 4.3. These theories complement each other and are suitable to interpret teachers' needs and level of support in online teaching.

### **3.1 *Effective Professional Development (PD)***

PD can be defined as processes intended to enhance the professional knowledge, skills, and attitudes of teachers so that they might, in turn, improve student learning (Borko, 2004; Guskey, 2002). PD can take two forms: formal and informal, with the former structured and including face-to-face workshops, distance education courses, and instructional coaching which seeks to facilitate change in teacher's practice through a coaching partnership (Mangin & Dunsmore, 2015, as cited in Stoetzel & Shedrow, 2020). These activities introduce teachers to educational innovations and evidence-based methods of teaching in their respective content areas. The latter is usually open-ended, flexible, and self-directed and includes conversations between colleagues and accessible online learning platforms, which requires high motivation and self-regulation (Beach, 2017).

Gibbons and Cobb (2017) identified five dimensions for designing PD opportunities – they should be ongoing; address authentic problems of practice; support inquiry into student thinking; build teacher communities as spaces to endorse and refine professional discourse; and engage pedagogies of investigation and enactment to translate findings into practice. Similarly, McQuiggan (2012) discusses several components for successful PD such as recognizing faculty needs, individualized plans, utilizing faculty experience, providing a learning environment that respects and supports teachers, active participation, reflection, collaborative inquiry, observation of online courses, authentic context, action plan, and ongoing support.

Research has documented the importance of PD in general, and for online teaching, in particular. Generally, teachers' PD activities that foster self-directed learning can contribute to higher levels of motivation for learning and the implementation of pedagogical and content knowledge in practice (Beach, 2017). McQuiggan (2012) noted that learning to teach online had the potential to transform faculty assumptions and beliefs about teaching and even change their face-to-face instruction practices. It also resulted in more connections and expertise sharing with colleagues. In-service and pre-service teacher training can positively impact their perspective about technology use and technology application in education, empower them, enhance their confidence, and result in greater engagement in self-directed, collaborative, and reflective learning (King, 2002; Luo et al., 2017).

Despite the affordances of PD, school districts face several implementation challenges. In response to the lack of financial or resource capacity, online PD is increasing as it offers choice, ownership, and connectivity to educators (Stoetzel & Shedrow, 2020). Nevertheless, the overall quality of the offered PD is still in question despite the exponential growth of online teaching (Barbour & Harrison, 2016). Barbour and Harrison (2016)

report on the effectiveness of some teacher education and in-service systemic PD initiatives in enhancing teachers' understanding of and interest in the design, delivery, and support of K-12 online learning. Reiser (2013) recommends that for PD opportunities to be successful, they should be embedded in subject matter; involve active and collaborative learning; be connected to teachers' own practice; be part of a coherent system of support; and capitalize on cyber-enabled environments.

### **3.2 Social Constructivism**

Vygotsky's (1978) sociocultural theory of human learning describes learning as a social process, in which social interactions affect cognitive development. Learning occurs through communication with peers and experts or seniors in a real-life context (Wang & Ha, 2012). Since most teachers in this study were also learners of new approaches and strategies, they were co-constructing knowledge of online teaching.

Wang and Ha (2012) state that teachers' learning is impacted by individual and social factors. Prior knowledge and experience are examples of individual factors that can facilitate or inhibit teachers' PD. Individual factors also include technological competence, teacher beliefs, and learning and teaching experiences. In addition to these factors, social factors also influence teachers' perceptions and practices in online teaching settings and should be considered in teacher learning (Wang & Ha, 2012). For example, social factors include the social culture, school context, social interaction with peers, government policy, teacher support, and professional culture. It is thereby important to analyze teachers' views through this lens.

### **3.3 Communities of Practice**

Parallel to social factors influencing teachers' learning is Wenger's (1998) communities of practice, defined as groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly. Wenger's model consists of four interdependent components: community, practice, meaning, and identity. In a community, members engage in joint activities and discussions, help each other, and share information. They build relationships that enable them to learn from each other. What makes communities of practice unique are shared domain of interest and social engagement of the participants engaged in learning. Research highlights the importance of these communities as they can positively impact teachers' learning, capabilities, and pedagogical practices (Luyten & Bazo, 2019). They also result in more collaboration and resource sharing among teachers (Shi & Yang, 2014; Warren Little, 2002). Thus, it is crucial to investigate how communities of practice informed teachers' online teaching practices, especially given that many teachers were teaching online for the first time.



## 4 Methodology

### 4.1 Research Design

This study utilizes a mixed-methods design (Creswell & Creswell, 2018) involving the collection of both closed-ended quantitative data and open-ended qualitative data. The two forms are integrated through merging the data, explaining the data, or building from one database to another. This integration minimizes the limitations of both approaches and provides a more comprehensive understanding of the phenomenon, specifically teachers' experiences in ERT. In this study, both quantitative and qualitative data were collected from teachers through an online questionnaire. Quantitative data provided a broad and general overview of the level of support provided to teachers, while qualitative data provided in-depth and detailed accounts of their experiences (Merriam & Tisdell, 2015).

Participant recruitment methods included snowball sampling through teacher networking and referral (Parker et al., 2019). Teachers were invited to participate in the study through email from school boards and teacher associations. In addition, researchers and consenting teachers recruited additional participants via social media (e. g., Twitter, Facebook, LinkedIn).

### 4.2 Participants

The questionnaire was administered to STEM teachers ( $n=75$ ) from various locations in a Canadian province. Participants included STEM subject teachers (biology, chemistry, environmental sciences, physics, earth sciences, general science, technology, and mathematics). Participants' educational background included those with bachelor's degree (71%), and graduate degrees (masters or doctorate – 29%). In terms of age, 72% of the teachers are between 31–50 years, 16% between 21–30 years, and 12% are above 50 years. Teaching experience varied with 15% of the respondents having less than five years teaching experience, while 85% have more than 5 years of teaching experience (24% between 6–10 years, 38.5% between 11–20 years, and 22.5% above 20 years). Finally, 51% of the participants teach elementary and middle-school grades (grades 1–8), while 49% teach high school (grades 9–12). Table 1 details the distribution of teacher demographics in relation to each age range. It is worth noting that, while the majority of teachers have a bachelor's degree, most of the teachers with a graduate degree are between 31–50 years of age and possess between 6–20 years of teaching experience.

Table 1. Details of teachers' demographics: distribution of teachers within each age range.

Age (years)	Sample (n)	Grades taught		Educational background		Teaching experience (years)			
		Gr. 1–8	Gr. 9–12	Bachelor's	Graduate	1–5	6–10	11–20	20+
21–30	16%	8%	8%	12%	4%	12%	4%	0%	0%
31–40	25%	16%	9%	18%	8%	0%	14%	12%	0%
41–50	47%	24%	22%	33%	14%	3%	5%	21%	17%
51–60	9%	3%	7%	7%	3%	0%	1%	5%	3%
61+	3%	0%	3%	1%	0%	0%	0%	0%	3%
Total	100%	51%	49%	71%	29%	15%	24%	38%	23%

Note: One teacher did not indicate their class taught, and two teachers did not indicate their educational background.

### 4.3 Data Sources

Data sources for the overall study included questionnaire statements and open-ended questions, developed based on the previously discussed theoretical frameworks and literature, taking into consideration the ongoing ERT. This chapter reports on a sub-section of participants' responses to 3-point Likert scale items and open-ended questions from the larger study. The questionnaire statements and open-ended questions explore teachers' i) challenges, ii) support during transition to online teaching, and iii) recommendations for enhancing the quality of online teaching.<sup>3</sup>

The following four Likert scale items required participants to rank the value or benefit (Inadequate, Average, or Excellent) in terms of preparing them for ERT:

- 1) *School or school board support*
- 2) *Departmental support or community of practice*
- 3) *Quality of resources at your disposal (ministry and other)*
- 4) *Professional development focusing on online teaching*

3 Data presented is part of a larger study which explored i) STEM teachers' views of and attitudes towards online teaching, ii) tools and resources teachers used during online teaching, iii) development and implementation of curriculum to be taught online, iv) models of student assessment, and v) impacts of online teaching on student outcomes, as observed by teachers.

Teachers' reflections regarding their practices during ERT were obtained through the following two open-ended questions:

- 1) *List some challenges that you face(d) as a teacher while preparing for or implementing online teaching. Please elaborate on how you address(ed) these challenges.*
- 2) *Please suggest additional strategies that the Ministry of Education needs to consider in order to enhance the quality of online teaching experiences for students and teachers alike.*

#### **4.4 Data Analysis**

While the initial plan was to collect data from 100 STEM teachers, this chapter is based on 75 participants as data saturation (Charmaz, 2006, as cited in Creswell & Creswell, 2018) occurred in qualitative data. This was evident through initial and ongoing data analysis performed through Qualtrics, the web-based software used for data collection, whereby new categories and themes beyond those identified were not prevalent. Concurrently, similar trends were occurring in quantitative data. Accordingly, the authors ceased data collection. Quantitative data was exported to Microsoft Excel while qualitative data was exported to NVivo 12 data analysis software.

Quantitative data analysis was conducted in MS Excel using descriptive statistics including calculating percentages, averages, and standard deviations, as well as constructing bar graphs. Qualitative data analysis from open-ended survey questions was performed as an inductive process that builds patterns, categories, and themes by organizing the data into more abstract units of information (Creswell & Creswell, 2018). The qualitative data were analyzed through an interpretational analysis framework, using NVivo 12 and executed through the process of thematic coding and constant comparative method (Stake, 2020). Initial codes were created in NVivo 12 through word clouds that illustrated emerging codes as well as their frequency based on the size of the font (word frequency query). These codes were then explored and interpreted in order to seek context as some words carry equal or similar meaning; similar codes were combined into themes. Both authors performed thematic coding in which themes were analyzed for frequency across participants (see sample in Figure 1).

													Please suggest additional strategies that the Ministry of Education needs to consider to enhance the quality of online teaching experiences for students and teachers alike.
													Clear time boundaries for teachers
													Centralized high-quality digital resources & platform
													Access to quality technology for teachers and students
													Additional IT and PD support
													Clear administrative direction
													Accountability measures for students
													We need cameras, microphones, multi-frame recording studio software (face-cam, document cam, secondary monitor capture). This cost me some money, but let me be able to respond to students in an efficient and HUMAN way that they could relate to. They clearly stated their appreciation for seeing and hearing a known adult as opposed to text based learning or being sent to youtube to learn from experts. Additionally, we need CLEAR messaging on if we are to teach in a sync way or not, and what exactly that means.
		0	0	1	0	1	0						Use tech savvy teachers within each school and use them to mentor/support teachers within their respective school with any tech related issues etc. And, be available for support.
		0	0	0	1	0	0						Uniform platform for everyone. Students need an orientation resource on this platform as well as parents. I spent several hours walking students and/or parents through getting to them online. Make the material that is completed online 'count' to ensure higher student participation. Have resources on every aspect of Brightspace accessible to teachers now and hire staff to walk teachers through using it now. Teachers will use what they can understand.
		1	1	0	1	0	1						They need to make more apps available to teachers so that we can use them with our students without having to pay for a membership. Examples of apps that would be useful: Pixton, RAZKids, ixl, video creation software.
		0	1	0	0	0	0						The Ministry needs to communicate clear and consistent expectations for students and staff right from the beginning. The constantly changing expectations for students and teachers was very challenging to adapt to and interpret as the pandemic went on and schools were closed for longer and longer. The Ministry could help support teachers with providing subscriptions to useful online tools like Gizmos and Screencastify... A lot of work would have to be put in in order to update the Learn at Home website to make it more useful to students and teachers.
		0	1	0	0	1	0						Teachers need training on how to incorporate adequate material (ie voice thread)and it needs to be mandated across the province of how online learning will look. This training needs to happen before we go back online. Universities are preparing profs, and TAs but the same is not being done at the k-12 level and it sets everyone up for failure.
		0	0	0	1	1	0						

Figure 1: Sample thematic coding exploring teachers' recommendations for improving online teaching

## 5 Results

### 5.1 Teacher Support and Professional Development

In this section, quantitative findings resulting from the 3-point Likert scale items and related to the level of support provided to teachers during ERT are presented. As shown in Figure 2, teachers reflected on i) support they received from school/board; ii) departmental or community of practice support; iii) quality of the resources; and iv) PD. The two major areas needing improvement, according to participating teachers, are the quality of online resources at their disposal and the PD they received. Questionnaire statements reflecting the quality of resources received the highest ranking in terms of inadequacy, while the PD statement resulted in the lowest ranking in terms of excellence. On the other hand, the support provided by departments and communities of practice received the highest ranking in terms of excellence and the lowest ranking in terms of inadequacy compared to the other three items.

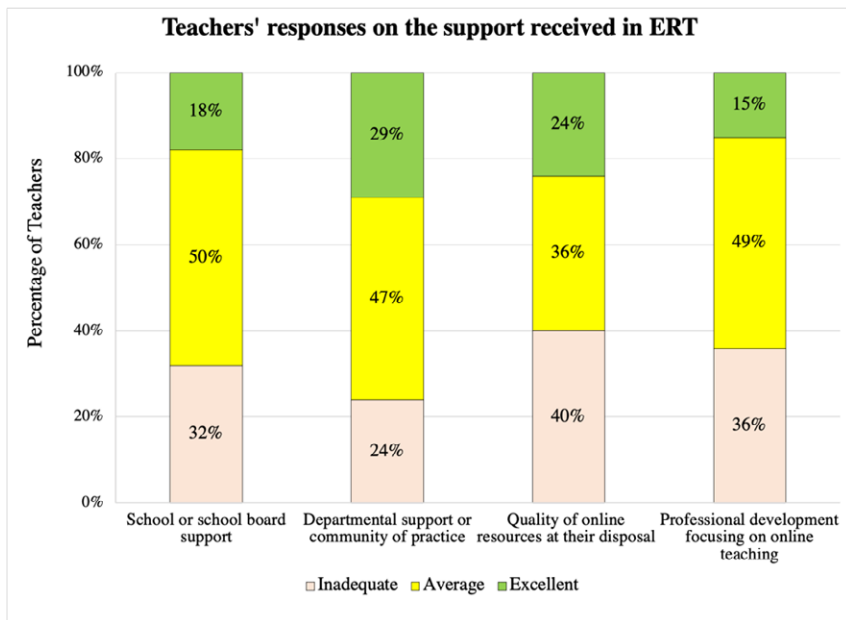


Figure 2: Teachers' evaluation of the support they received during ERT

Teachers expressed frustration towards the lack of prior exposure to the needed technologies and PD opportunities:

PD was insufficient and the courses always full. (Secondary science and math teacher)

I have been teaching for more than 20 years and I know what I am doing in a real classroom, not in a digital one! (Elementary science, technology, and math teacher)

Correspondingly, one of several teachers expressed a similar frustration with the available resources:

The lack of resources meant I often had to reinvent the wheel. I couldn't find the resources I needed online because I teach French Immersion, so I had to create most of my resources for my students. (Elementary science & technology, math, and health & physical education teacher)

In terms of support received from the school board or the ministry, one teacher noted:

It was 100% new to me and I had to figure it out independently. There was no timely guidance or assistance. I was able to do it through research I completed on my own time using resources created by other teachers. The Ministry was of no help and my school board offered help weeks after we had started to teaching full time online. (Elementary science & technology, math, and health & physical education teacher)

On the other hand, the support teachers received from their departments or communities of practice was relatively better, according to participants:

Through collaboration with my grade team, we were able to provide students with variety of learning opportunities. They were provided instruction to run their own science experiments at home and participate in hands on math activities. They were also provided with many online resources to engage with on their own time. (Elementary science, technology, and math teacher)

My department has worked very closely on a daily basis – helping each other and sharing resources- we have a group chat and text each other nonstop. (Secondary biology teacher)

## 5.2 Recommendations for Online Teaching

This section presents teachers' recommendations to various stakeholders for improving online teaching in the future. These findings are based on qualitative data resulting from three open-ended questions in the questionnaire. STEM teachers listed several recommendations for consideration by school boards, policy makers, and the government. The corresponding themes derived from the qualitative data include clear time boundaries for teachers; centralized high-quality digital resources and uniform online learning platform; quality technology for teachers and students; additional IT and PD support; developmentally appropriate digital resources for students; clear administrative direction; and enforcing accountability measures for students to encourage student participation.

These recommendations can be classified into three categories: i) student and teacher resources, ii) administrative, and iii) training. As shown in Figure 3, in terms of student and teacher resources, teachers demanded a) centralized high-quality digital teaching resources and a uniform learning platform (57%); and b) quality technology (i. e., internet, document cameras, computers, etc.) for students and teachers (31%).

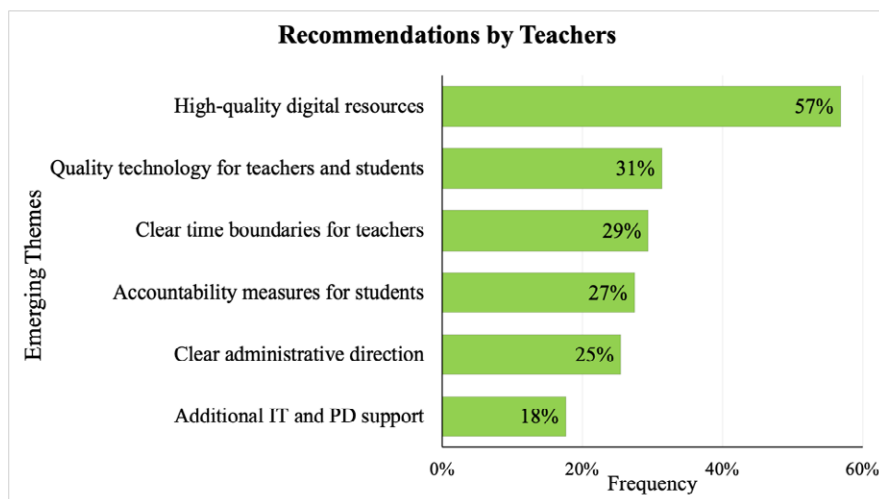


Figure 3: Recommendations by teachers for successful online teaching in the future



Findings highlight the fact that teachers were not satisfied with the quality of the resources provided. They did not have the digital tools they needed to implement high-quality online learning in the time provided. This made initiatives such as synchronous learning a challenge. They also spent a lot of time finding and modifying free resources for students. They demand that digital resources be developmentally appropriate for students. Furthermore, teachers prefer teacher-recommended and teacher-created digital resources rather than generic ones, as they are more pedagogically relevant to their context:

They need to make more apps available to teachers so that we can use them with our students without having to pay for a membership. (Elementary science & technology, math, and health & physical education teacher)

The materials (on the Ministry website) were outdated in many courses and was all information based with no evaluation suggestions. A lot of work would have to be put in in order to update the website to make it more useful to students and teachers. (Secondary biology teacher)

With respect to technology, teachers expressed their personal and their students' need to access quality equipment and fast internet:

Teachers don't have the equipment and resources to teach from home. I personally spent 1000 dollars to teach with only marginal effectiveness. So, money for hardware and software. (Secondary technology and computer studies teacher)

I was recording several videos every day and scanning in documents with slow, old equipment at home. This took up my whole workday. (Secondary math teacher)

In the area of technology, teachers emphasized the importance of equity among students, especially in terms of access to technology for learning:

Children need better technology if we are doing online. Each child in household needs a device. Training for some parents is also needed. (Elementary science, technology, and math teacher)

The Ministry of Education needs to ensure all students, especially those in rural settings have access to the technology and internet speed required for online learning. (Elementary science, technology, and math teacher)

In the category of administrative recommendations, three themes emerged based on teachers' responses: i) clear time boundaries for teachers (29%); ii) accountability measures for students (27%); and iii) clearer administrative directions (25%).

Time management was a fundamental challenge for teachers. They expressed the need or the expectation to be available for prolonged periods of time. Moreover, teachers had to deal with very new technologies and environments. This forced them to spend more time becoming acquainted with these technologies, prepare for their classes, and interact with their students, as outlined below:

(I need) time to prepare! While I may have not always worked 8 hours straight, many times I did, and it was broken up and was somewhat steady from 7 am till 10 PM. Regularly responding to

emails late or having meetings in the evening. (I need) course content time. I teach 4 grade levels and 2 different academic levels, and 3 different courses of study. That is roughly 10 different courses I have to prepare for. (Secondary technology and computer studies teacher)

Teachers are very busy. In Grade 12 courses, unit evaluations were pretty frequent (about one every 1.5 weeks), and that would take about 20 hours to mark (with over 90 grade 12 students in total). It takes a lot longer to mark virtual work on a computer. (Secondary math teacher)

Regarding student accountability, teachers expressed disappointment in the public announcement that online student assessment would not contribute towards final grades, which resulted in a lack of engagement from students, as noted in the following teacher quotes:

One of the reasons that the students lost interest in engaging in online learning was the ministry's announcement of midterm mark would be the final mark. In order to have good quality online learning the expectations must be clear and same as the in-class learning. (Secondary physics and math teacher)

Not counting (student work) devalues the efforts of the students and makes it challenging to motivate them. (Secondary math teacher)

As for administrative directions, teachers demanded clearer and more unified expectations, enhanced teacher involvement in decision making, and the removal of mandated synchronous learning:

Consult teachers before making public plans. Nothing worse than fielding stress, questions, and concerns from parents and students when you get the information after them or at the same time. (Secondary science and math teacher)

Promote teacher professional judgement. Place the trust in the teachers to utilize and enact policy within schools and classrooms/online. (Secondary science and math teacher)

Finally, in terms of IT support and PD, 18% of teachers felt overwhelmed as they tried to navigate the digital learning space in terms of providing content and learning at the same time. While there were online board provided PD sessions, these were limited in capacity or not effective. Teachers recommended:

Much more PD. There are about 5000 teachers in my board. The classes I managed to sign up for had 36 attending. Most classes I tried to sign up for were full. I want to learn. I want to be a good teacher. This is taking too long by trial and error. (Secondary science and math teacher)

Teachers need training on how to incorporate adequate material (i. e., voice thread) and it needs to be mandated across the province of how online learning will look. This training needs to happen before we go back online. Universities are preparing profs and teaching assistants, but the same is not being done at the K-12 level, and it sets everyone up for failure. (Elementary science and technology teacher)

## 6 Discussion

### 6.1 *Teacher Support and Professional Development*

Findings pertaining to the levels of support received by the teachers (as shown in Figure 2) highlight specific challenges. These include lack of effective PD and scarcity of quality resources, which are two crucial factors contributing to the success of online teaching, especially during unprecedented conditions. Teachers' evaluations of the quality of PD offered by school boards further reinforce the need for better preparation to acquire the seven online teaching competencies, as outlined by Pulham and Graham (2018). Teacher training and in-service PD focusing on online teaching tools would enable teachers to learn how to utilize the necessary technological skills effectively (Barbour & Harrison, 2016; Davis et al., 2007; Jung, 2005; Smith et al., 2016; Stoetzel & Shedrow, 2020). The lack of appropriate digital resources further supports claims of current deficiency in instructional designs and valuable online resources (Cook & Steinert, 2013; De Paepe et al., 2018). Organizing digital educational content to align with existing curricula can be critical in providing users and teachers with a way to ensure that the learning opportunities provided correspond to broader educational objectives within an education system (World Bank, 2020). On the other hand, teachers' positive rating of departmental support and communities of practice further emphasizes and renews the call for capitalizing on the expertise of these groups to maximize their effectiveness. This highlights the importance of communities of practice (Wenger, 1998) and collegial support as examples of social factors necessary for teacher learning (Vygotsky, 1978; Wang & Ha, 2012).

### 6.2 *Recommendations for Online Teaching*

Findings indicate that teachers' recommendations were aligned with challenges they encountered and the level of different kinds of support they received. On the availability of quality digital resources, Recker et al.'s (2004) findings suggest that teachers use a broad range of resources that they deem age-appropriate, current, and accurate. Moreover, teachers intend to include these resources with little modifications into planned instructional activities. Our findings highlight teachers' recommendation of developmentally appropriate digital resources that are aligned with curriculum. The availability of these resources, in a unified platform that students and teachers are familiar with, is crucial for the success of online teaching.

On the importance of access to technology among students, teachers' recommendations reiterate the documented literature on addressing equity concerns with respect to students' access to the required technologies, including software and equipment that impact their opportunities to participate in online learning (Lao & Gonzales, 2005; Rohleder et al., 2008).

Finally, in the category of administrative recommendations, teachers documented institutional challenges that they face in online teaching, similar to those reported in the literature (see Bolliger & Wasilik, 2009; Cook & Steinert, 2013; De Paepe et al., 2018). Such challenges are critical as they impact teachers' attitude towards online teaching. Furthermore, these recommendations fall into the category of sociocultural factors that impact teachers' knowledge construction (Vygotsky, 1978; Wang & Ha, 2012). With respect to the importance of ensuring and maintaining student accountability reported by teachers in this study, Toppin and Toppin (2016) highlight that student discipline is crucial for success in a virtual school setting. This factor can be a challenge, especially when students are in isolation from other peers, as in ERT during the COVID-19 pandemic.

### **6.3 Limitations**

Due to the social distancing measures implemented, online questionnaires were the most convenient means of data collection in the setting of a large Canadian province. As well, given that teachers were busy throughout the period of data collection (May–July 2020), and to avoid additional stress and increased workload, we chose not to interview participants. While this may be considered a limitation to the research design, the unique circumstances during the COVID-19 pandemic necessitated such a measure. In spite of this limitation, the researchers ensured the collection of rich qualitative data via open-ended questions that detailed teachers' experiences during ERT. Another limitation in this study is reliance on self-reported responses by teachers which may increase bias. The authors believe that collecting timely data during ERT outweighs the highlighted limitations. Thus, the integration of quantitative and qualitative data from a relatively large sample during ERT enhances data trustworthiness and validity.

## **7 Conclusions**

The overall results of the study demonstrate a general dissatisfaction and negative attitudes toward online teaching among the participating STEM teachers during the COVID-19 pandemic. Teachers expressed that the support they received did not match their expectations. The two major areas of improvement noted are the quality of online resources at teachers' disposal and the PD they received, as indicated in Figure 2 – quality of resources generated the highest ranking in terms of inadequacy, while PD generated the lowest ranking in terms of excellence. These factors exacerbate challenges faced by teachers and could potentially foster negative attitudes toward and low self-efficacy in online teaching, as reported by DeCoito and Estaitayeh (2022).

This also echoes the importance of teacher training and PD focusing on online teaching tools so that teachers learn how to utilize the necessary technological skills (Davis et al., 2007; Jung, 2005; Leire et al., 2016; Smith et al., 2016; Stoetzel & Shedrow, 2020). So-

rensen et al. (2007) found that science teachers who learned about technology in their teacher preparation program were prepared to use technology in more substantive and meaningful ways. This also mirrors previous findings on the importance of PD around teachers' technological and pedagogical content knowledge to achieve desired change (DeCoito & Richardson, 2018). An effective change in teachers' practices cannot happen by simply introducing technological tools and infrastructure into schools or by traditional one-time teacher training. PD should entail initial preparation and training for pre-service teachers; workshops, seminars, and short courses for in-service teachers; and ongoing pedagogical and technical support for teachers as they address their daily challenges and responsibilities (DeCoito & Richardson, 2018).

On the other hand, findings indicate that teachers appreciated most the support received from departments or communities of practice, as indicated in Figure 2 – communities of practice generated the highest ranking in terms of excellence and the lowest ranking in terms of inadequacy compared to the other three items. This reiterates the importance of communities of practice that can serve as repositories for teachers to share their expertise and resources. Hence, teachers can build relationships that enable them to learn from each other in preparation for nimble adjustments, such as those necessitated in transitioning to online teaching during the pandemic. One example of PD programs is a recent initiative developed by the OECD (2020), that combines teachers' online communities of practice, PD, and digital resources. The initiative, "The Global Teaching InSights" makes use of technology in building teachers' collective intelligence by creating and sharing the "know-how" of teaching. This initiative enables teachers to work together and tackle the challenges of teaching by having deep and meaningful conversations with their peers around the world. It entails a digital platform for the teaching community, that makes teaching visible through classroom videos and instructional materials and provide teachers with a space to reflect and interact with their peers from around the globe. Such programs and initiatives are very crucial in assisting teachers and sharing expertise among teachers from a wide range of backgrounds and experiences.

Teachers suggested several recommendations to ministries of education, policy makers, and school administrators, as shown in Figure 3. These included investing in high-quality technological resources such as highspeed internet, computers and free software aligned with curriculum standards; developing a database of free high-quality bilingual digital resources in accordance with curriculum expectations; accountability measures to encourage student participation; reconsidering allotted time and workload required to plan and implement high-quality online education; and more effective PD opportunities. These recommendations align with Hodges et al.'s (2020) criteria for successful transtion to ERT during crisis states. Decision makers must address these important recommendations given the prevalence of ongoing online teaching during the pandemic.

Teachers in this study emphasized students' equitable access to technology. This finding reiterates the importance of stakeholders attending to inequities among families and communities, which impacts teaching and learning. Moreover, moving to online learning at scale magnifies profound equity concerns especially that differences still exist between rich over poor, urban over rural, high-performing over low-performing, students in highly educated families over students from less educated families, and for students with disabilities who have particular and individual needs that must be met (World Bank, 2020).

## **8 Implications and further research**

This research will advance knowledge about online teaching at K-12 levels. Moreover, it will inform government, policy makers, and school administrators about the challenges associated with online teaching. Findings are being shared with the education community through seminars and working groups and provide teachers with opportunities to reflect on and assess their current practices and explore other teachers' practices. The recommendations suggested by the teachers are crucial as teachers' voices need to be heard to enhance the quality of online teaching in the future.

Future research can explore teachers' online teaching approaches in various Canadian provinces, especially the Canadian territories, the home of Indigenous communities. Moreover, we recommend that similar research explore student perspectives to obtain a holistic view of teaching and learning. A handful of studies have been conducted with students at the post-secondary level (for example, Petillion & McNeil, 2020; Wilcox & Vignal, 2020); however, there is a scarcity of studies involving K-12 students and their experiences during ERT. It is also recommended that future research compare various time periods during the pandemic, for instance comparing the period of March–June 2020 to September 2020–June 2021. This will help identify changes in practice after an extended period of preparation, and less disruptive conditions. On an additional but important note, this research will help develop a solid framework that can be used in assessing online teaching needs and practices in emergency situations. Finally, we need to investigate the reported challenges more thoroughly and explore how they can be dealt with through PD programs for in-service teachers, as well as more robust preparation for pre-service teachers.



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