

THE USEFULNESS OF TECHNOLOGY IN TEACHER PROFESSIONAL DEVELOPMENT: EXTENDING THE FRAMEWORKS

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Abstract: *We describe three major challenges that teachers of STEM subjects face in their preparation and practice. Then, we discuss how technology could become a vehicle for providing timely and content-related support. To this end, we suggest a theoretical framework, which builds on the works of Vygotsky, Shulman, and Mishra and Koehler. Specifically, we use the notion of zone of proximal development to accentuate educators' professional growth and ideas from the activity theory to put educators' deliberate actions and learning in the wider context of peer learning. Then, we use this framework to describe two professional learning models, each from a different STEM field. This paper will be of interest to STEM educators and facilitators of professional learning activities, as well as developers of education technology resources.*

Key words: STEM teachers, professional development, education technology

Introduction

The 21st Century Challenges

In the second decade of the 21st century, mathematics and science teachers and teacher-educators faced tough challenges. **The first challenge** is a growing dissatisfaction of the general public and the governments with the mathematics and science education in our public schools. While governments ask for improved student scores on international assessments and for skills adequate for future workplace, media and parents ask for *back-to-basics* (OECD, 2016a, 2016b). The rapidly changing demands for teachers, oscillating between the calls for back-to-basics and improved scores on standardized testing versus the calls to incorporate inquiry-based learning and

encourage creativity, critical thinking, and other soft skills, even if it means a reduced emphasis on the development of content-specific skills and abilities, are especially taxing for new teachers (British Columbia Ministry of Education, 2015; Kennedy, 2016; OECD 2016a). These ongoing curricular reform fluctuations have significant implications for students, parents, and of course, teachers (Cuban, 1990; Fullan, 2007).

This problem is exacerbated by **the second challenge**—the growing diversity of the student population and the limited opportunities modern families have for supporting the academic studies of their children outside of school. It happens for many reasons, including parents' increased work commitment, their limited academic background or language proficiency, or the

lack of parents' familiarity with the school curricular demands (Milner-Bolotin, 2017). While this challenge has implications for all school subjects, mathematics and science are especially affected (Van der Zalm, 2010). These subjects have a hierarchical structure and require a solid foundation, dedication, significant time investment, and appreciation from both students and parents.

The third challenge is related to the emergence of the science, technology, engineering, and mathematics (STEM) field. With the blurring of the subject and discipline boundaries, mathematics and science are now often placed under the STEM education umbrella, whereby teachers are expected to be able to draw curricular connections between the subjects. This challenge is even more critical in the countries like Finland, in which the curriculum integration is a compulsory part of the new curriculum (Niemelä & Tirri, 2018). Without proper support, this expectation is certain to get teachers out of their pedagogical comfort zone.

The implications of these challenges on teacher education and professional development (PD) are still unclear (Ben-David Kolikant, Martinovic, & Milner-Bolotin, 2019; also see OECD, n.d., 2030 project). Moreover, with the rapidly changing K-12 STEM-related curricula around the world, inclusion of new subjects and subject areas such as computer science, computer programming, robotics, environmental science, computer modelling, and technology education, mathematics and science teachers may be expected to teach less familiar content and use pedagogical approaches that they did not have a chance to experience as students (Lieberman, Ben-David Kolikant, & Beeri, 2012; Martinovic & Manizade, 2014; Martinovic & Zhang, 2012). Because the latest curricula also put more emphasis on competency-based assessment (e.g., British

Columbia Ministry of Education, 2015; Ontario Ministry of Education, 2014, 2016), teachers must refocus their assessment practices and reconsider how they evaluate student learning outcomes (Milner-Bolotin & Moll, 2008).

The Need for Different PD and the Potential of Technology

In order to address these challenges, teachers need ample support in the form of mentorship, accessible teaching communities of practice, and ongoing PD. However, in many developed countries teachers still have limited access to ongoing and on-demand PD, such that is relevant to their contexts, local curricula, pedagogical and technological innovations they are trying to implement, and personal needs. There is ample research evidence that the traditional practice of an intermittent and piecemeal PD is ineffective (Darling-Hammond, Hyler, & Gardner, 2017, Fullan, 2011; Opfer & Pedder, 2011; Phillips, 2014; Smylie, 2014; Trust, Krutka, & Carpenter, 2016; Wei, Darling-Hammond, & Adamson, 2010). In this practice, the teachers spend a handful of PD days a year outside of their classrooms participating in activities imposed by their administration. Beyond these sporadic PD days where they can meet and discuss with their peers, teachers often work in isolation getting limited mentorship or support for implementing these educational innovations in their classrooms. With the current climate of reduced educational funding in Canada and elsewhere, it would be unrealistic to expect that teachers' access to relevant face-to-face PD opportunities will improve dramatically in the near future.

The persistent failure to address these challenges has motivated us to examine the role of modern educational technology in providing meaningful PD for teachers. Despite the proliferation of digital technology

in everyday life and in schools and its increased social value, these novel tools are yet to be utilized deliberately to enhance STEM teacher PD (Milner-Bolotin, 2016; OECD, 2016a). In fact, the success of innovative PD programs in the 21st century depends on different factors. These factors include but are not limited to teachers:

(1) ability to benefit from online collaborative PD forums; (2) mastery of the variety of problem-solving strategies for resolving conflicts related to their local school environment; and (3) prior conceptions about teaching and learning, and the compatibility of these concepts with the reformed instructional pedagogy. (Russell & Schneiderheinze, 2005, p. 38)

Russell and Schneiderheinze (2005) observed four teachers who “had the same amount of technology, software and hardware, and the same amount of previous [technology] training” (p. 42). The authors found that each teacher approached and benefitted from online PD in a unique way. Some reasons for such a variety were internal, such as having “differing beliefs about the learning potential resulting from the unit [and] differing abilities to collaborate and problem-solve as innovators”; while some were external, such as dealing with “differing context issues” (p. 42) at their workplace. However, the commonality was that none of the teachers used the online environment to its full potential, neither for collaborating with peers nor for working with students. The researchers recommended that teachers’ prior experiences with technology, local school community, and pedagogical conceptions must be taken into account in developing any similar program. Although the research evidence supports the claim that the most promising innovations that strive to improve teaching do so by improving collaboration and peer learning between teachers (Fullan, 2011; Winthrop, McGivney, Williams, &

Shankar, 2016), this aspect is difficult to accomplish.

What Do 21st Century Teachers Need to Know?

Nowadays, it is widely accepted that all workers should be critical thinkers and problem solvers; team players and collaborators; technology users, and self-directed and lifelong learners (Partnership for 21st Century Skills, 2006). Additionally, educators need to be role models as creative and flexible thinkers; seekers of emergent possibilities; reflective and informed practitioners, who continually plan, implement, assess, and innovate (Literacy and Numeracy Secretariat, 2010). In this context, being informed practitioner means knowing the subject and being well-informed in the educational advancements and curricula.

Beijaard, Verloop, and Vermunt (2000) described teachers’ professional identity as a blend of three aspects: subject-matter expertise, pedagogical expertise, and didactical expertise. Compared to secondary school teachers, who are most often subject-matter specialists, elementary school teachers are for the most part generalists making development of this aspect of professional identity particularly difficult. This issue was raised by Shulman (1986) more than three decades ago when he pointed out to the *missing paradigm problem* that is especially prevalent among elementary school teachers. The second aspect, pedagogical expertise (Beijaard et al., 2000), relates to the ideas of how people learn and what pedagogical approaches could facilitate their developmental trajectories. The third aspect, didactical expertise, relates to knowing how to assist learning of the specific subject (i.e., pedagogical content knowledge [PCK]; Shulman, 1986). However, it has been well established that teachers benefit less from

receiving prescribed knowledge, as compared to personalized approach from someone who knows what the teachers are experiencing and who can make the PD relevant to them. The teachers appreciate guidance on the enactment of the content knowledge, a format that yet has to be adopted across the system as the PD programs still largely address general pedagogical prescriptive issues, while paying less attention to the subject-specific pedagogical knowledge and teachers' intellectual engagement (Kennedy, 2016; Phillips, 2014).

A Novel Theoretical Framework for Teacher Professional Growth with Technology

The theoretical framework suggested here builds upon Milner-Bolotin's (2016) framework termed *deliberate pedagogical thinking with technology* (DPTwT). The DPTwT highlights the role of educational technologies in the initial development of physics teachers' professional knowledge. It relies on the notions of technological pedagogical content knowledge [TPCK] (Mishra & Koehler, 2006) and the zone of proximal development [ZPD] (Vygotsky, 1978). To these, we added aspects of activity theory, which enabled us to extend the DPTwT beyond the intended physics teachers' professional knowledge to include the mathematics and science with technology.

Technological Pedagogical Content Knowledge

During the last half a century, education researchers have suggested multiple conceptual frameworks to describe professional knowledge of teachers. It started with Shulman (1986) who proposed that pedagogical content knowledge (PCK) is what distinguishes teachers from other professionals. The PCK is a combination of the subject-specific content knowledge (CK)

and the general pedagogical knowledge (PK). The PCK was later expanded to include the knowledge of educational technologies, technological knowledge (TK), thus morphing into the TPCK (Mishra & Koehler, 2006). The latter framework separates the CK (i.e., the knowledge of specific STEM disciplines) from the knowledge of how these subjects could be taught in the K-12 context (PCK), and the knowledge of how technology could be used to enhance student learning of the discipline in the context (TPCK). While CK is usually acquired by future teachers during their undergraduate studies, PCK and TPCK develop during teacher education and different forms of professional lifelong learning.

Zone of Proximal Development

Soviet psychologist Lev Vygotsky (1896-1934) noticed that children have a potential to learn more when they are supported by peers or adults. He called the difference between what children can do unassisted and what they can do while assisted, as ZPD. To take a full advantage of one's ZPD and to expand one's knowledge and skills, the social environment should provide scaffolds of learning.

In the literature, the concept of ZPD was extended to any learning situation, as well as to "the training of adults to learn complex tasks frequently encountered in the use of information systems" (Verenikina, 2003, p. 6). Holzman (2006) noted that "unlike young children, adults need the added support of conceptual learning, of stepping back and abstracting the 'lessons learned' from ... experiential learning activities" (p. 21). This is especially relevant for teachers, who must always learn, update and question their knowledge, interact with others in the field, and continuously reflect on their practice. The view of ever-evolving mastery of teaching and the importance of a community in

becoming and being an effective teacher is situated in Vygotsky’s ideas:

Vygotsky saw human growth as a cultural activity that people engage in together, rather than as the external manifestation of an individualized, internal process or the lawful pattern of responses to external stimuli. Growth and transformation don’t happen *to us*; we create them. In both his research and theorizing, Vygotsky presented a new methodology for understanding human life as lived, with a particular focus on child development, learning and teaching as collaborative, creative, cultural activities of continuous transformation. (Holzman, 2006, pp. 9–10; emphasis in original)

Deliberate Pedagogical Thinking with Technology

The notion of continuous transformation through collaborative learning and teaching activities (Holzman, 2006) is the crux of the DPTwT (see Figure 1). It was originally developed to describe the growth of TPCK (Mishra & Koehler, 2006) of science teachers as a result of their engagement with educational technologies and other educators. It used the ZPD (Vygotsky, 1978) to emphasize the role of peers in professional learning and define the teacher ZPD (T-ZPD) as the gap between what a teacher has already mastered (the actual level of development, as expressed by their current TPCK) and what they can achieve when provided with opportunities to collaborate with peers and more experienced educators. Through collaboration, teachers’ TPCK can grow much more effectively than had they worked in isolation.

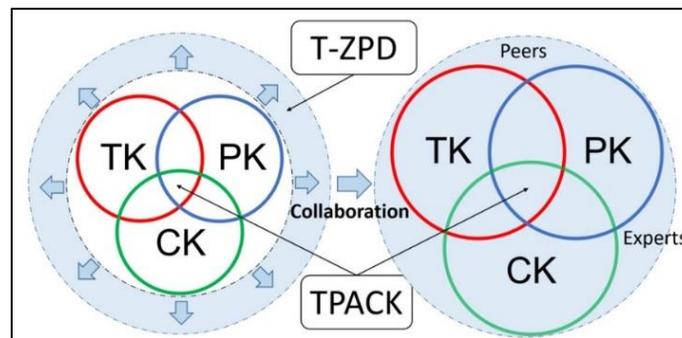


Figure 1. DPTwT framework (Milner-Bolotin, 2016)

The DPTwT framework is built on five major assumptions about the multi-faceted nature of teachers’ knowledge for teaching; it is

1. based on PCK (Shulman, 1986), knowledge of psychology and of the science of learning, as well as on pedagogically sound use of modern technologies;

2. subject- and context-specific, thus, elementary and secondary teachers might possess different kinds of knowledge, and the same can be said about teachers from different subject areas, cultures or geographic areas;
3. continually evolving— teachers’ professional knowledge can grow and expand during their careers, but it also can

diminish (or die) if they stop learning. Aligned with Carol Dweck’s (2006) idea of growth mindset, teachers are foremost learners whose professional knowledge can thrive in a supportive learning environment;

4. acquired through academic studies, professional practice, reflection, and collaboration with colleagues, students, and parents; and
5. necessary but insufficient for successful teaching practice, as it has to be coupled with appropriate attitudes and dispositions that comprise educator’s teaching philosophy.

Extending the DPTwT Framework

The extended DPTwT framework is the result of our analysis of the original DPTwT components, based on which we revised the original diagram (see Figure 2). It is important to mention that while this framework was initially applied to STEM teacher education, it can be applied to other subjects. We identified four aspects, which need to be considered in planning and executing PD programs. These are (a) focusing on specific types of technologies, (b) focusing on growth of TPCK, (c) balancing TPCK components, and (d) creating supportive environments.

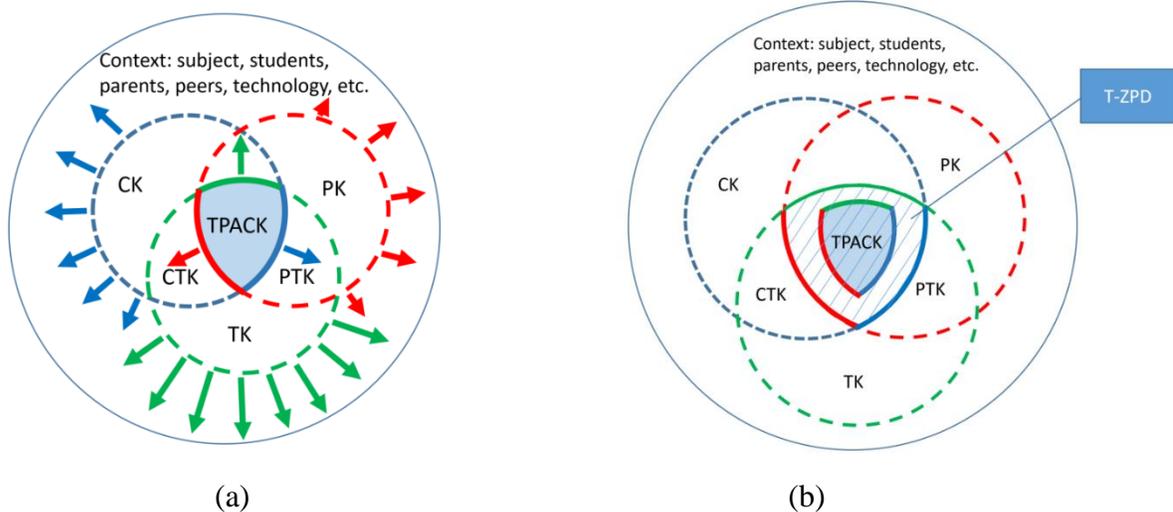


Figure 2. (a) Extended DPTwT framework focuses on the growth of TPCK through peer collaboration in a technology-supported community of practice; (b) different facets of teacher professional knowledge grow at different rates causing the overlap (TPCK) to grow as well.

Focusing on specific types of technologies.

To avoid danger of bringing too many different kinds of technologies under the unified technology umbrella, we consider as especially relevant the subject-specific technologies, such as calculators, computers, and digital sensors, as well as communication technologies, such as computer networks. While the former may be used synchronously in individual or group work, the latter ones

also allow for asynchronous exchange of information and collaboration at distance. Consequently, the extended DPTwT framework considers technology as both a tool that can support teachers in deliberately promoting student learning, using subject-specific technologies, such as GeoGebra or PhET, and as tools that can promote teacher collaboration and PD (through Skype, Google Hangouts, social media tools, etc.).

Focusing on growth of TPCK. Each of the teacher professional knowledge facets (CK, PK, and TK) can grow at different rates, but as they grow, it is important to ensure that the overlap between them—the TPCK grows as well. Our experience tells us that the boundaries of each facet of teacher professional knowledge are porous, which signifies that in a professional learning situation it is almost impossible to address one kind of knowledge without affecting the others. Partially, the problem lies in the TPCK framework, for which the validation studies suggest “that measuring each of [the subdomains, e.g., PK, CK, and TCK] is complicated and convoluted, potentially due to the notion that they are not separate” (Archambault & Barnett, 2010, p. 1556). Additionally, teachers are required and known to be reflective individuals who relate every situation to their teaching practice. For example, the PD event may discuss assessment and working with specific populations of students (e.g., children with special needs) without having an explicit intent to expand the knowledge of the discipline (CK). However, with the increase of the PCK, there will be some positive effects on the understanding of concepts as well. Alternatively, the workshop facilitator may use technology during the workshop to demonstrate how children learn using it, and although the TK is not a target, the teachers’ TCK will be increased, which will positively affect their TK. Of course, that does not mean that any PD with technology would do.

Balancing TPCK components. With the idea that teachers’ PD should address TPCK, and take into account the educators’ and children’s needs, each of the CK, PK, and TK

should be dealt with to some extent. However, this would only work if the PD facilitators address the TPCK, while consistently:

- using non-trivial examples from the discipline that are clearly related to the curriculum. Using trivial examples, as it is often done, will not only fail to increase one’s CK, but will be de-motivating; the same goes to using examples that are too difficult or those that are far-removed from the curriculum;
- using various kinds of up-to-date technology that is available to teachers and students. For example, using free smartphone apps or software that teachers and students have free access to (Maciel, 2015);
- attempting to match pedagogy with technology and content. Failing to do so has negative consequences. For example, insisting on individual work and preventing students to work in groups, does not align with the best practices to learn mathematics and does not use the advantages of collaborative technologies available in schools.

Creating supportive environments. To provide adequate scaffolds through a collaborative and technology-based professional learning, the extended DPTwT framework borrows from Engeström’s (1987) version of the activity theory, which included the components of community, division of labor, and rules (see Figure 3). It emphasized that the professional learning is an activity that uses the intelligence of others—evident in tools, discourse, and communal supports—as a lifeline.

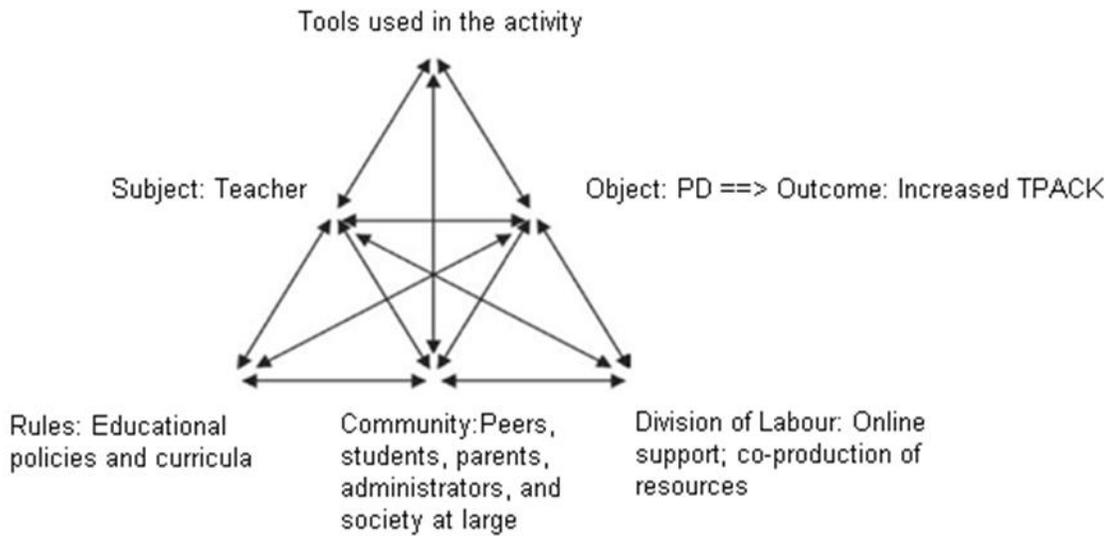


Figure 3. Engeström’s (1987) model applied on a supportive professional learning environment.

The upper triangle of Figure 3 can present the activity of individual teachers, which results in their increased TPCK (i.e., the outcome). Teachers’ growth is mediated by the tools they use, as Jonassen and Rohrer-Murphy (1999) stated, “tools mediate or alter the nature of human activity and, when internalised, influence humans’ mental development” (p. 66–67). Tools could be material objects but also symbols, signs, images, language, and technology (Martinovic, Freiman, & Karadag, 2013). The lower part of the triangle represents activity as influenced by interactions with peers, students, parents, administrators, and the society at large. The rules include the policies and the curricula. The arrows exemplify relationships and influences. Edwards (2007) pointed out that “new forms of [professional] practice are being required which call for a capacity to work with other practitioners and draw on resources that may be distributed across systems to support professional actions” (p. 1). Edwards called this capacity relational agency and defined it:

As a capacity [relational agency] can be learnt and elicited in different situations. It is not embedded in existing relationships and carefully designed pedagogic zones of proximal development but may emerge in both formal and informal settings and with people who are known and as yet unknown. It allows us to work with others in pursuit of ever expanding objects and to explore the possibilities that these new objects reveal. (p. 6)

In summary, the extended DPTwT framework views teacher knowledge as evolving through collaboration with peers, mediated by the use of technologies. This extended framework also emphasizes different dimensions of teachers’ knowledge and their overlaps that contribute to the formation of this very specialized professional knowledge, in our case—the knowledge for teaching STEM subjects (see Figure 2).

Using Extended DPTwT Framework to Examine Learning in the Existing Teacher Education and PD Models

In this section, we introduce two PD models with educators teaching STEM subjects and analyze them using the extended DPTwT framework.

UBC Online M.Ed. in Science Education Program

The University of British Columbia offers an online M.Ed. in Science Education program (UBC Faculty of Education, 2019). The program has been designed as a sustained PD opportunity for practicing K-12 teachers of science in order to bridge educational research and practice, while engaging teachers in an education community facilitated by university educators and researchers. Its courses are limited to 20 participants in order to create a vibrant online community. The program also operates in a cohort form and usually takes two years and one semester to complete, as most of the participants are also part-time or full-time educators and are not expected to take more than two online courses per term. In addition to completing all the coursework, the participants must write a graduating paper or create an online portfolio reflecting how the theoretical knowledge they acquired in the program could enhance their professional practice.

This program uses educational technology in multiple ways. First, it uses it to create a collaborative learning environment for teachers who are located in different parts of the country and could not have met face-to-face. Collaboration is supported by an online course management platform, while utilizing online collaboration tools such as Collaborate Ultra, Google Hangouts, Skype, etc. The focus on creating a community of learners is deliberate. Technology helps teachers to get

to know and feel comfortable with each other, identify each other's strengths and weaknesses, and feel open to reaching out and collaborating. Thus, it becomes a mediating tool for supporting peer learning through collaboration.

Second, this technology-enabled learning community of teachers opens opportunities for identifying and expanding different facets of knowledge for teaching of individual educators through utilizing their individual T-ZPD. Some teachers in the program have extensive PK, CK, or PCK, while others might have more knowledge of technologies and their pedagogical applications.

Third, having elementary and secondary educators in one cohort opens opportunities for collaboration on science education that rarely happen, as these teachers traditionally have limited communication with each other. All the courses in the program emphasize collaboration and reflection, while providing educators with many opportunities to experience educational technologies as learners, reflect on them as teachers, and attempt to implement them in their own classrooms, as practitioners (Milner-Bolotin, Fisher, & MacDonald, 2013). This facilitates the growth of different aspects of teachers' professional knowledge.

Fourth, this online program invites the participants to experience various educational technologies in the context relevant to their own teaching, collaborate and learn from and with each other, and provide and receive feedback from peers and the course instructors (Milner-Bolotin, 2015). This approach deliberately aims at utilizing teachers' T-ZPD for the purpose of growth of their professional knowledge. It is especially important, as the program includes experienced as well as relatively new teachers, so both groups can benefit from online collaboration.

Finally, the courses in the program examine research methods in education, science teaching and learning with technology, design and evaluation of technology-enhanced science learning environments, as well as specific educational technologies and educational assessment (Milner-Bolotin, 2016). The choice of courses allows program facilitators to capitalize on teachers' strength and help address their weaknesses. For example, one of the courses titled, *Mathematics and Science Teaching and Learning through Technologies*, invites teachers to experience different educational technologies and design relevant technology-based PD events they can implement in their schools.

In summary, technology is used deliberately throughout the M.Ed. in Science Education program to promote pedagogies suitable for active engagement of graduate students and, along, modeling active engagement of students in elementary and secondary schools (Milner-Bolotin, 2016). Continuous reflection, feedback from peers and multiple iterations of the assignments, as well as using technology for enabling ongoing teacher collaboration, facilitate the evolution of teachers' professional knowledge for teaching science (Milner-Bolotin, 2019).

Online Professional Learning of Mathematics in Ontario

In 2017-2018, the Ontario Ministry of Education personnel (most of whom were previously in the leadership and administrative positions in their districts) led the educators' professional learning of mathematics in a program called, The Math Pod. They used social media (e.g., on-line radio program, project website, and Twitter; Brown, 2012) to create opportunities for professional "learning and knowing as situated, social, and distributed" (Putnam & Borko, 2000, p.5). This was done in the

context in which each elementary school was required to have 1-3 Math Leads tasked with supporting their peers in delivering curriculum content.

There were three rounds of The Math Pod each lasting four weeks. More than 800 participants signed up for the sessions. The online environment and multimedia materials mediated the exploration of carefully selected ideas for teaching mathematics. The labour was distributed between the facilitators who run the segments, interviewed guests, posted materials, and maintained the project website; guests who answered questions and offered supports; and participants who tweeted their classroom examples, asked questions, or provided advice and feedback. The researchers worked in the background, collecting data to inform the next round of this or other similar PD and to create summaries of activities for the project website. Relational agency of all was elicited, as this type of PD would not work without those involved having "capacity to offer support and to ask for support from others" (Edwards, 2007, p.1).

Overall, the educators positively evaluated contribution of The Math Pod to their learning, especially to their understanding of how to learn and teach mathematics. On average, the participants agreed with the statement, "I feel that the Math Pod activities made me more 'intentional' in my teaching and/or leadership of mathematics" (Donsky & Martinovic, 2018).

Modern Technology Contributions to Teaching as Viewed through DPTwT Framework Lens

The two examples provided above emphasize the role technologies could have in the educators' continuous professional learning. In the era of reforms and limited funds to support PD, using online opportunities for

formal (e.g., UBC online MEd in Science Education program) or informal professional learning (e.g., The Math Pod), is both cost-effective and suitable. For Westera (2005), the only option in which education could “meet the continually changing needs of society [is through] sensible application of new technologies” (p. 35). However, how can teacher educators do that? Achieving this task is not easy. Education practices are still for the most part intrinsically conservative, traditionally following a business model of “one man shops” (Westera, 2005). Teachers tend to work in isolation and behind the closed classroom doors. These isolation-oriented practices stifle innovation and are counterproductive with respect to the DPTwT (Milner-Bolotin, 2016) framework.

Also, we should be mindful that *more* does not automatically mean *better*. For example, the Ontario professional learning experience prior to The Math Pod utilized a variety of the latest technological options (e.g., a live radio show and its podcast recordings; Twitter; a book and its Facebook study group; items posted on the Google+ Groups; personal and collaborative blogs; quad blogs; and a newsletter) encouraging

- a. open online conversations on multiple platforms,
- b. documentation of learning shared openly in multiple formats, and
- c. scaffolded access to artefacts of learning through a single open access point (a website).

Sixteen out of 35 educators who completed the online exit survey reported having hard time to participate in activities. The respondents claimed to have spent on average 2.9 hours per week on this project (min = 1.5 h, max = 8 h). Many reported being challenged with using online technologies, and specifically navigating the many options that were provided to them. A group of educators advanced that they were lost at the

beginning of the process before figuring out how to engage in the best way that fits their preferences. One educator wrote

I found it extremely difficult to keep track of all the options, email, and newsletters. I would prefer communication from one source with all information in one resource. I feel that a 1 hour/week commitment turned into several hours over different days/time which I was unable to attend. As a result, I felt ‘out of the loop’ and disconnected from the process. I’m struggling with the work flow of Twitter. In order to add this to my day, I will have to remove something else. I’m not sure of the value of having people retweet my ideas or me retweeting others’ ideas. It can be flattering but I cannot say that anything that I have read on Twitter has changed my practice.

Despite these criticisms, most of the participating educators were satisfied with the overall learning experience, and 75% said that in the future they intend to participate in the similar professional learning. In their feedback, they suggested trimming the number of online features and concentrating on the most efficient ones. They mentioned that they learned how to use some technologies (e.g., blogs), but because of the intensity of communication and the number of online options, they felt intimidated to use these new features. They did not express the need to gain new technological skills, but rather to use those that provide the highest reward in terms of extending their PCK. One educator suggested to “include video conferencing options for on-line learning [being able to see the speakers in the radio show] or being on-line with a particular group of learners at a pre-arranged time,” while another expressed a need for “more practical resources to use. Coaching scenarios. Vignettes. Getting at real problems teachers are facing.” While they could not address all

the feedback in The Math Pod that followed, the facilitators provided a smaller variety of features (i.e., live radio show accompanied with Twitter chats, and followed by reflective blogging), but encouraged their use by all.

Conclusions and Recommendations

The potential of technology to support online professional learning and peer networks is well established. Preparing and supporting teachers who are ready and willing to take advantage of the 21st century opportunities to succeed in the current reality of increased expectations and frequent reforms is challenging; technology could be better used by educators in both micro (e.g., classrooms), meso (e.g., school-wide), and macro (e.g., province-wide or even country-wide) applications. To address both old and new challenges, teacher educators and PD organizers could provide both formal and informal professional learning options to teachers, using the extended DPTwT as a beacon. The extended DPTwT combines several powerful theories in order to show how these programs could be structured and researched.

The PD organizers should take into account their audiences and be deliberate in selecting not only activities but technologies as well. If the goal is to spread out the message, to inform, the most commonly used technology, such as Twitter, may be appropriate. If the goal is to gain a pedagogical or content-related skill, employing the technology that all can have access to and a good portion of participants have experienced at some point, is suitable. This will allow for more experienced peers to guide the newbies, whose ZPD will extend. Those in supporting roles will extend their T-ZPD because they will be providing scaffolds to others, sometimes in a similar way as to their students. Facilitators will have to differentiate activities and technologies to keep their

participants interested making sure they extend their ZPD. Sometimes providing extra activities (both advanced and simpler) may help but also not trying to challenge the audience in all three—PK, CK, and TK—at the same time. Instead, being very intentional in diversifying activities so that in one session, participants practice a progressive PK, while using the CK and TK at their comfort level; while in the next session, they engage in the activity extending their CK, while utilizing known PK and TK, and so on.

Online communication and access to online repositories of educational resources should be utilized to provide just-in-time support for teachers and teacher educators. Teachers are very busy and may need support in order to consider and adopt teaching methods they did not experience as students. Therefore, combining the educational materials (e.g., lesson plans, instructions) and video testimonials from those who used them with vignettes from the classrooms, as well as discussion forums/Twitter feeds might be very helpful to provide both informational and emotional support to teachers. After all, success in supporting STEM (and other) educators in the era of frequent curriculum reforms, intensified globalization, and breakthroughs in science and technology will require more work on extending their relational agency (Edwards, 2007). We call on teacher educators to consider how we can address contemporary educational challenges through creative use of technology in STEM teacher education and professional development.

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