Supporting Technology Integration in K-12 Classrooms: Putting the Puzzle of Professional Learning Guidelines Together

Christopher Godfrey, Schulich School of Education, Nipissing University, Canada

Abstract: This thematic review of the literature explores guidelines that can be used to create effective professional learning experiences in the area of K-12 classroom technology integration. Its findings highlight how guidelines have been scattered throughout the literature and are largely ignored by administrative stakeholders and institutional researchers. Gathering these guidelines to put the puzzle of effective learning together, it emphasizes the importance of including educators in the planning and implementation of learning experiences, and the tailoring of learning to their specific needs. It underscores that learning should be collaborative, generated from a grassroots level (instead of being prescribed from the top-down), have administrative support, and focus on pedagogical understandings, not just content knowledge.

Keywords: Education, Technology Integration, Professional Learning, Professional Development

The world continues its lockstep march with digitization, and K-12 educators have had to adjust pedagogy and practice to match. In a society demanding students be digitally literate, it is imperative that within today's classrooms, technology be readily integrated into teaching practices to help prepare students for the world and digital society they are a part of (Hrastinski, 2008; Johnson, 2020; Prensky, 2001). For this to take place, however, educators must be prepared themselves to integrate technology. It is readily accepted that enhanced knowledge of a digital resource aids in efforts to integrate it within teaching practices, and that professional learning should provide what is necessary for successful integration to take place (Ahadi et al., 2021; Godfrey, 2013; Kanaya, 2005; Paulus et al., 2020). Such learning may also help educators discover tools for teaching that they may not have been aware of and highlight how best to utilize digital technologies to support transformational pedagogies (Barton & Dexter, 2020; Chikasanda et al., 2012; King, 2002; Lawless & Pellegrino, 2007).

Professional development/learning in the area of classroom technology integration, however, has fallen short in supporting educators' initial and ongoing integration efforts. Facilitators of top-down learning approaches (such as employer mandated workshops, seminars, and lunch-and-learn sessions), typically decontextualize materials from the needs, desires, and unique contexts (such as resource availability and grade level/subject being taught) of those participating. This can render learning experiences relatively useless when participants return to their own classrooms (Cheng, 2019; Hall & Trespalacios, 2019; Paulus et al., 2020). While self-study (such as with a professional learning community[6]) may allow educators to contextualize their learning, they are rarely afforded the resources, time, and/or support necessary to ensure success (Barton & Dexter, 2020; Goodnough, 2018; Goodyear, 2016). Many educators simply do not feel comfortable using/integrating digital technologies in their classroom teaching practices or remain unaware of the pedagogical transformations such technologies are able to support (Ahadi et al., 2021; Cuban, 2001; Gill, 2019; Gurevich et al., 2017; Mishra et al., 2019; Mouza, 2003; Symons & Pierce, 2019; Tan et al., 2019).

Professional learning best practices in the 21st century are lagging behind what is necessary to support educators in their integration efforts (Bustamante, 2020; Chen, 2019; Coogle et al., 2021; Mishra et al., 2019; Tan et al., 2019). This challenge, however, is not a new one. As noted within this thematic review of the literature, over the last forty years several guidelines have been suggested for crafting effective professional learning in the area of educational technology integration in classrooms. Experiences and interventions created and implemented, however, have been inadequate in generating meaningful and lasting change to classroom teaching practices, and these inadequacies may be inhibiting classroom technology integration. This should alarm educational stakeholders, and a review of professional learning guidelines in this area is imperative to enable a rethinking of best practices.

6 For example, through social media connections including Facebook or Twitter.

Methodology—A Thematic Review

A thematic review of the literature was completed following the guidelines of Creswell and Guetterman (2019). In this form of review, "the author discusses only the major ideas or results from studies [as they pertain to emergent themes], rather than the detail of any single study" (Creswell & Guetterman, 2019, p. 101). This review consisted of three search frameworks. The first focused on the search terms "professional development", "teachers", and "technology". The second used "professional development", and "teachers"[7]. These searches were conducted within specific time periods to cover the origins of digital technology in schools to the present day: 1980-89, 1990-99, 2000-09, and 2010-22. A third framework was completed to better capture the modern era (2010-22) of professional learning and technology integration, with three searches completed. The first used "technology", "professional learning", and "teachers", the second focused on "professional learning" and "teachers", while the third included "action research", "professional learning", "technology", and "teachers". Searches were completed using all databases available through EBSCOhost.

For each search, fifty articles were initially reviewed, and sources were selected for relevance based on their titles and abstracts (Randolph, 2009). Snowballing of sources was also conducted using citations found within articles reviewed. Where necessary, Google searches were completed for background information. Following the guidelines of Becker (2007), vetted sources were closely examined and included for their richness of information and relevancy to this review. This includes both peer reviewed and professional sources as the nature of professional learning in education is discussed both academically (by researchers) and practically (by educators who may share their experiences/ideas/suggestions but not through a peer reviewed publication). No geographic context was included in the search as it is felt that the research topic is not specific to a single area. Most sources uncovered by these search frameworks were written within the United States and Canada, giving this literature review a decidedly North American focus.

Sources were examined and coded inductively until a point of saturation. Codes were then examined and reduced, with emergent themes identified. These themes highlight the various pieces necessary for professional learning to promote effective technology integration in classroom teaching practices. In summary, these themes include the need for learning to be contextualized to participants, to be collaborative in nature, teacher-developed rather than administratively mandated, supported through administrative resources, and focused on pedagogical understandings rather than just content knowledge of the underlying technology.

What Qualities Should Professional Learning Have?

The literature offers many suggestions for crafting personal learning experiences that support educators' technology integration efforts in their classroom teaching practices, which is to say learning that leads to meaningful and lasting change. Boser (1989) suggests involving stakeholders (students, teachers, parents, and administrators) in the planning, design, and implementation of the learning process; identifying and developing strategies to overcome barriers to integration; and providing opportunities for educators to participate in all stages of learning. Bramble (1980) believes that success requires a change in participants' behaviour, attitudes, and beliefs, but must be done as a series of small, incremental steps and include some tangible reward. Similarly, Birman et al. (1998) posit that effective learning emphasizes high levels of learning, focuses on specific content knowledge (relating to what participants teach), offers enough time to learn (with ongoing follow-up support), includes mentorship and collaboration among teachers, links with other learning initiatives being offered, and accountability for real change in teaching practices. These suggestions are mirrored by Berry et al. (2006), who argue that learning experiences must be relevant to the needs of classrooms, be hands-on in design, provide ongoing support, and provide opportunities for collaboration. While these researchers offer key guidelines, a wider review of the literature reveals that each of them individually only holds a few pieces of the puzzle; effective professional learning appears to require a coming together of these pieces to form a holistic experience.

[7] Technology was not included in the second set of search terms to determine if these issues (related to the foundations of professional learning) exist beyond the scope of training related to technology in the modern era.

In this section, guidelines from across the literature have been gathered to showcase a more complete picture of professional learning recommendations from the last forty years across technology and non-technology related learning. In summary, it is believed that learning experiences must include educators in the planning, design, and implementation of the experience. The experience must be ongoing, rather than short lived. The learning must be relevant and contextualized to the needs of participants, and collaborative in nature. It should be led from the bottom-up (teacher developed), rather than top-down (administratively mandated), but must have the support of administrators to be successful. Finally, effective learning experiences must also focus on pedagogical understandings of technology integration, rather than just content knowledge of technology. These guidelines, however, have often been ignored by those responsible for researching and/or implementing learning experiences in this area.

The Inclusion of Educators and Necessity of Contextualization

Adult learning theory, a cornerstone of any learning experience involving educators, suggests that learning must be experiential in design as adult learners are autonomous, self-directed, practical, and relevancy oriented (Damewood, 2016; Johnson, 2020; Kelly, 2012; Loveland, 2012; Schrock, 2012). There must be attention paid to the motivations of participants and the intensity of the process and outcome, as participants tend to lose motivation and/or have difficulty maintaining focus of long-term goals in low-intensity programs (Carliner, 2013; Kanaya et al., 2005). A key guideline for professional learning in this area, then, must be to include participants in the planning, design, and implementation of learning interventions. Logically, it is the best way to determine what the needs and wants of participants will be, what resources they have available to them, the needs of their own students, and how they will/want to integrate technology into their classroom practices.

To facilitate the creation of more effective experiences, the literature suggests that participants must be a part of planning, design, and implementation in several key areas, including scheduling, content, and collaboration. Effective learning experiences are learner-centered, built on participants' strengths and knowledge, are tailored to their individual wants and interests, and held within a contextualized setting relevant to their classroom needs (Berry et al., 2006; Chen, 2019; Curtin et al., 1994; Darling-Hammond & McLaughlin, 1995; Duran et al., 2012; Kent, 1985; Kerr, 1989; Novick and Grimstad, 1999; Vrasidas & Glass, 2007). Hew and Brush (2007) further point out that professional learning needs to address the immediate concerns of an educator rather than focusing broadly or generally—a 'just in time' model of learning, rather than a 'just in case' model. They found that the relevancy of the experience to the participant was "the most influential factor contributing to teachers' integration of technology into their classrooms" (p. 239). As such, any process that generates a professional learning experience for educators must consult with participants on their needs, wants, and interests to ensure the learning they undertake is relevant and contextualized to their classroom environment. This includes determining what they want to learn about, how it fits into their pedagogical understandings of technology integration, the resources (including time) that they have available to them, and how they want to learn.

As seen in the literature, however, these guidelines have often not been considered by stakeholders in their research and/or creation of professional learning experiences in this area. Allan and Miller (1990) and Buss and McClurg (1999) suggest that much of the learning done in the 1980s and 90s had little impact on classroom practice because of limited collaboration between researchers and their participants. This can be seen further in the work completed by Bodzin (1998), Cleland and Rilleo (1996), Denton and Manus (1995), Koch (1996), Novick and Grimstad (1999), the Pelavin Research Institute (1998), Pennell and Firestone (1998), Schmidt (1997), and Schrum (1991). The ignoring of participants' needs, wants, and environmental contexts continued throughout the early 2000s (Barnett, 2003; Breiner, 2009; Ince et al., 2006; Rosaen et al., 2003), the 2010s (Chikasanda et al., 2012; Duran et al., 2012; Lemon & O'Brien, 2019), and today (Bustamante, 2020; Coogle et al., 2021). In short, concerns about participants not being given a voice in the development of their own professional learning experiences have continued through the last forty years of technology integration in classrooms.

A Need for Teacher-led Development, not Administrative Mandates

Administrative demands, including new policies, instructional practices, or curricular undertakings, can attempt to push educators into changing their teaching practices. These can come from principals, school boards, or various levels of government (Anderson, 1997; Harvey & Carpenter, 2020). Given the participant-driven nature of effective professional learning, however, it stands to reason that grassroots-led initiatives should guide the creation of learning experiences, rather than the prescription of learning from above. Top-down initiatives (learning in which the content of the learning, when the learning will take place, and how it will be learned are all mandated by a school's administration, board office, or government directive), especially without the input of educators, rarely yield desired results (Barnett, 2003) and may hinder technology integration when leadership does not understand how or why digital devices can/should be integrated into classrooms (Birman et al., 1998; Bliss & Bliss, 2003; Harris et al., 2009; Hew & Brush, 2007; Sheffield et al., 2018). This can lead to resentment among educators in cases where an administration demands teachers learn something that they have no interest in or is not relevant to their needs (Carliner, 2013; Schrum, 1991). In some cases, this can also lead to wasteful spending as devices go unused (Berry et al., 2006; Cuban, 1993; Hixon & Buckenmeyer, 2009; Lawless & Pellegrino, 2007; Miller & Glover, 2007).

Any innovation or integration of technology in classrooms, then, must be motivated from the bottom-up rather than the top-down. This is not a new concept, as it was noted in 1986 that "The teacher who is treated as the mere tool of reform becomes instead its saboteur" (Educational Technology Center, p. 15). As Kerr (1989), Meister (1990), and Novick and Grimstad (1999) note, educational leaders may not understand the contextualized needs of a teacher or their classroom while making policy decisions, especially when the structure of modern educational hierarchy does not ground its decision making in the needs, wants, or interests of teachers and their practices (as seen in the lack of inclusion of educators in the planning, design, and implementation of learning experiences noted above). A bottom-up approach (in which content, goals, and timelines are determined by participating educators) to learning is necessary to ensure that an experience matches the needs of participants and their classroom environments (Barnett, 2003; Bergmark, 2020; Barton & Dexter, 2020).

With that said, the literature also highlights the need for educational leadership in this process, as professional learning requires the support of administration to be successful (Bliss & Bliss, 2003; Educational Technology Center, 1986; Novick & Grimstad, 1999; Meister, 1990; Mouza, 2003; The National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983). McEvoy (1987) discusses how principals can support their teachers in professional learning by highlighting opportunities available to them, as well as disseminating resources and materials, working collaboratively to determine areas of needed learning or interest from staff. They also note that principals can work to generate learning that is co-designed and implemented collegially, rather than prescribed from above. Another way this collaboration can be supported is by including principals in the professional learning experience in order that they too should benefit from increased understanding of integration efforts (Hew & Brush, 2007). Many, however, highlight how often the notion of administration fertilizing grassroots-led learning has been ignored, and instead showcase how school administration (Birman et al., 1998; Hawkins-Segar, 1980; Meister, 1990; Pelavin Research Institute, 1998; Schrock, 2012) or educational researchers (Breiner, 2009; Caverly et al., 1997; Darling-Hammond & McLaughlin, 1995; Glazer, 2009; Hall & Trespalacios, 2019; Hennessy, 2014; Koch, 1996; Lee et al., 2017; Moltudal et al., 2022; Shaka, 1998; Sheffield et al., 2018) have told participating educators what they will learn, when they will learn, and how they will learn.

Administrators should work in conjunction with educators, and vice versa, to support professional learning that meets the needs, wants, and interests of teaching staff. This includes scheduling, content, and collaboration in learning. Teacher-generated professional learning experiences will not flourish in the absence of resources and support from administration given the plethora of other responsibilities and challenges they face in their daily teaching practice. It is difficult to ask an educator to take on additional learning on their own time and expect them to embrace the opportunity of more work for no pay. Administrators who do not pay attention to the needs, wants, and interests of educators but instead push unwanted learning on their staff may instead find technology integration withering in their schools. A delicate balance of bottom-led initiatives and top-down resources should be struck to ensure that professional learning experiences are successful, long lasting, and lead to meaningful change in classroom teaching practices.

Experiences that Should be Ongoing

Single-day workshops have long been the standard for professional learning in this area, preferred because they offer a relatively cheap and easy way to educate large numbers of educators quickly (Ahadi et al., 2021; Berry et al., 2006; Bramble, 1980; Bustamante, 2020). Throughout the literature across the decades examined, however, a number of researchers note that these one-shot learning sessions are not effective in enacting meaningful and lasting change (Ahadi et al., 2021; Birman et al., 1998; Bybee & Loucks-Horsley, 2000; Goodyear, 2016; Pelavin Research Institute, 1998; Schmieder, 1981). As Mouza (2003) writes, "traditional sit-and-get training sessions without follow-up support have not been effective in preparing teachers to integrate classroom technology" (p. 273). A key issue is that with most sessions lasting less than four hours, they lack the time and engagement necessary for participants to return to their classrooms feeling confident in their technology integration efforts. Despite this, one-shot workshops with a lack of on-going follow-up support have been, and continues to be, an incredibly popular format for teacher-training in this area (Berry et al., 2006; Bramble, 1980; Bustamante, 2020; Bybee & Loucks-Horsley, 2000; Darling-Hammond & McLaughlin, 1995; Goodnough, 2018).

While learning must be ongoing, the barrier of time should also be considered by those crafting learning experiences, as educators tend to drop out of lengthy learning programs (Sherman et al., 2010), especially those with inflexible scheduling (Hew & Brush, 2007). Rather than shorten programming opportunities, however, more release time (built into a teachers' schedule) should instead be given to educators to engage with this learning. Learning experiences must be a part of an educator's ongoing professional practice, rather than a small part of their career (Aldridge et al., 2020; Bliss & Bliss, 2003; Goodnough, 2018; Kimmel et al., 1999; Vrasidas & Glass, 2007); such commitment, however, requires time outside of teaching duties but within the teaching day.

Ongoing support for learning should be offered throughout the process, not just at the beginning (Donoahue, 2020; Laitsch, 2020; Lotherington, 2020; Mouza, 2003; Lawless & Pellegrino, 2007; Shaka, 1998). No more one-size fits all single afternoon one-and-done workshops; the learning needs to be continuously ongoing year after year. This is especially important as educational technology changes rapidly, and in every decade of the literature reviewed there have been those who warn that what has been learned once will quickly become obsolete (Armstrong, 2013; Bustamante, 2020; Caverly et al., 1997; Cleland & Rilleo, 1996; Delgado et al., 2015; Gurevich et al., 2017; Hartsell et al., 2010; Heinch, 1980; Loveland, 2012; Olds Jr., 1981).

Collaborative Efforts to Foster Growth

Learning is a collaborative effort, and professional learning is no different when done effectively (Goodnough, 2018; Lawless & Pellegrino, 2007). The Educational Technology Center's (1986) conference report argues that educators need continued and ongoing support for their own learning in the form of mentorship from their peers. Harasim and Johnson (1986) recommend that professional learning takes place in an environment of collaboration rather than an environment of demands from an authority figure to learn. Kent (1985) and Glatthorn (1987) posit that cooperative professional development is imperative for growth and suggests that small teams work best for this approach. They also believe that peer supervision/coaching assists in this process, as those with more experience can assist those with less in either a formal or informal setting.

Novick and Grimstad (1999) offer a similar approach, suggesting that peer mentoring (with both mentor and mentee as learners supporting each other) is the most effective way to conduct professional learning. They also believe that school-to-university partnerships (academics working with educators to discuss research and practice/encourage inquiry), as well as the building of communities of practice (teacher-to-teacher networks to support inquiry and learning) are instrumental in guiding collaborative professional learning endeavours. Such collaboration in professional learning has also been suggested by DuFour and Reason (2016); Rosenau (1980), Ginting and Linarsih (2022), Glazer et al. (2009); Moltudal et al. (2022), Schrum (1991), and Wildman and Niles (1987). The Educational Technology Center's (1986) conference report goes even further, arguing that this collaboration should continue outside of the school and involve not just educational leaders, policy makers, educators, and students, but also parents, members of the community,

and the technology industry as well. Morris et al. (2003) suggest combining professional learning experiences that occur outside of the school with mentoring opportunities for individuals to share what they have learned within the school.

As such, any process that generates a learning experience for educators should work to foster connections between groups (either from the same school, or at higher levels including school board, provincial, national, and international levels) to support the inquiry and exploration process, as well as fulfill the previously mentioned commitment to ongoing learning over the span of an educator's career. This process should work with educators to determine how collaboration can be included and fostered in their learning experience and provide methods for it to be inclusive and ongoing. Despite this, Harasim and Johnson (1986) suggest that learning had often been done in relative isolation during the 1980s. Birman et al. (1998) note that collaboration in this area did not appear to increase through the 1990s. Hartsell (2010) reports participants feeling they did not have enough time for collaborative learning, and Ahadi et al.'s (2021) systematic literature review (2000-2020) found that collaboration was only mentioned as a key component of 4% of the studies examined. Of the studies included in Ahadi et al.'s (2021) review, collaboration was a key focus of only seven researchers (Allan & Miller, 1990; Armstrong, 2013; Barton & Dexter, 2020; Martin et al., 2010; Rosaen et al., 2003; Sheffield et al., 2018; Stager, 1995), and while suggesting the importance of collaboration, it was not a component of Liu's (2012) or Mouza's (2003) learning interventions.

Pedagogical Knowledge is Required

Professional development/learning experiences have often been concerned with the fundamentals of technology (for example, turning a device on and off) rather than with how to effectively integrate that technology into classroom teaching practices. This is referred to as content knowledge of technology, rather than pedagogical knowledge of integration (Birman et al., 1998; Bybee & Loucks-Horsley, 2000; Coogle, 2021; Dickman et al., 1996; Hartsell et al., 2010; Mouza, 2003; Stager, 1995; Wilkerson et al., 2016). As Vrasidas and Glass (2007) note, "for faculty to be able to act as experts in integrating technology, they need to have the knowledge, skills, and expertise to teach with technology" (p. 88). Mouza (2003) suggests that educators who received both content and pedagogical knowledge in a professional learning experience report higher levels of confidence with technology, as well as more effective integration efforts. In cases where educators have only received content knowledge, Hew and Brush (2007) found that technology use was typically limited to substituting technology for traditional learning, rather than generating a transformative learning experience for students through technology integration.

While content knowledge offers a foundation that educators must have to use technology, to ensure integration of that technology professional learning experiences must go beyond content and focus on transformative pedagogy as well (Chikasanda et al., 2012; Hew & Brush, 2007; Mouza, 2003). For this reason, pedagogical learning is included as one of the core pillars of the Technological Pedagogical Content Knowledge (TPACK) framework, designed to increase technology integration in classroom teaching practices (Bustamante, 2020; Ginting & Linarsih, 2022; Gurevich et al., 2017; Harris et al., 2009). As Wilkerson et al. (2016) note, however, a key limitation to this framework is that it does not offer specific details on what the professional learning experience should be.

Like other guidelines included in this review, pedagogical knowledge has often been left by the wayside in learning experience creation. The fragmented approach to professional learning, seen by Lawless and Pellegrino (2007), "does not meet the ongoing pedagogical needs of teachers and is often too far removed or disconnected from day-to-day classroom practice" (p. 594). Content knowledge was noted in Alayyar and Fisser (2019), Berry et al. (2006), Bramble (1980), Breiner (2009), Bustamante (2020), Coogle (2021), Curtin (1994), Ince et al. (2006), and Lee et al. (2017).

It is only through professional learning experiences that offer hands-on integration and pedagogical learning that change in classroom teaching practices can occur (Hartsell et al., 2010). Any learning experience that is created must first take into consideration participants' varying levels of technological ability with the devices under study and provide content learning as needed. That learning, being ongoing, must then shift to assisting educators in exploring the underlying pedagogical understandings that allow for technology integration in classroom teaching practices. As noted above, this is only achievable when teachers' needs,

wants, and interests are considered in the planning, design, and implementation of the learning experience to ensure relevancy within their contextualized teaching environments.

Where Does Professional Learning go From Here?

In 1981, Schmieder suggested that every new decade since the 1950s had been celebrated by educational leaders as *the* decade that educational technology would truly arrive, and that this arrival would fundamentally change the way teachers teach and students learn. Despite having four decades of experience creating guidelines to facilitate effective professional learning experiences, interventions related to technology integration in classroom teaching practices have been, and remain, limited in their ability to enact real and lasting pedagogical change.

Educational technology, even today, has not *arrived* in the sense policy makers have believed it would. It is clear from the literature that several foundational principles for professional learning have been established and can be used to generate effective learning experiences related to technology integration in classrooms. It is also clear that, in many cases, such guidelines have been ignored. This has led to a trichotomy between what educational leadership believes technology integration should be, what researchers feel should be done to improve technology integration in classrooms, and the classroom teaching practices of educators.

With many suggesting that professional learning has been inadequate in each of the last four decades, seen in the repeated limitations of technology integration and lack of transformational learning taking place as a result, a change needs to be made. It is time to rethink learning experiences for educators and put into place systems that work collaboratively with teachers to fulfil their needs, wants, and desires. This novel approach should be ongoing, the learning should be contextualized and relevant to the needs of individual classroom environments, and it should have the support from administrative stakeholders. The learning should also go beyond technological content knowledge and include a focus on curricular-specific pedagogical knowledge of technology integration.

REFERENCES

Ahadi, A., Bower, M., Lai, J., Singh, A., & Garrett, M. (2021). Evaluation of teacher professional learning workshops on the use of technology - A systematic review. *Professional Development in Education*, 1-17. http://doi.org/10.1080/19415257.2021.2011773

Alayyar, G., & Fisser, P. (2019). Human and blended support to assist learning about ICT integration in (pre-service) teacher design teams. In J. Pieters, J. Voogt, & N. P. Roblin (Eds.), *Collaborative curriculum design for sustainable innovation and teacher learning* (pp. 191-204). Springer Open.

Aldridge, J. M., Rijken, P. E., & Fraser, B. J. (2020). Improving learning environments through whole-school collaborative action research. *Learning Environments Research, 24*, 183-205. https://doi.org/10.1007/s10984-020-093180x

Allan, K. K., & Miller, M.S. (1990). Teacher-researcher collaboratives: Cooperative professional development. *Theory Into Practice, 24*(3), 196-202.

Anderson, S. E. (1997). Understanding teacher change: Revisiting the Concerns Based Adoption model. *Curriculum Inquiry, 27*(3), 331-367. http://doi.org/10.1080/03626784.1997.11075495

Armstrong, A. (2013). The digital toolbox: An introductory guide to collaboration technology. *The Learning Forward Journal, 34*(1), 26-27.

Barnett, H. (2003). *Technology professional development: Successful strategies for teacher change*. ERIC Clearinghouse on Information and Technology.

Barton, E. & Dexter, S. (2020). Sources of teachers' self-efficacy for technology integration from formal, informal, and independent professional learning. *Educational Technology Research and Development, 68*, 89-108.

Becker, H. S. (2007). *Writing for social scientists: How to start and finish your thesis, book, or article* (2nd ed.). University of Chicago Press.

Bergmark, U. (2020). Teachers' professional learning when building a research-based education: context-specific, collaborative and teacher-driven professional development. *Professional Development in Education*, 1-15. https://doi.org/10.1080/19415257.2020.1827011

Berry, J. S., Graham, T., Honey, S., & Headlam, C. (2006). A case study of the issues arising when teachers adopt the use of a new form of technology in their teaching for the first time. *International Journal for Technology in Mathematics Education, 14*(3), 150-160.

Birman, B. F., Reeve, A. L., & Sattler, C. L. (1998). *The Eisenhower Professional Development Program: Emerging themes from six districts*. United States Department of Education.

Bliss, T. J., & Bliss, L. L. (2003). Attitudinal responses to teacher professional development for the effective integration of educational technology. *Journal of In-Service Education, 29*(1), 81-99.

Bodzin, A. M., Park, J. C., & Grable, L. L. (1998, January 8-11). Teaching instructional materials for science educators with a CD-ROM and a World Wide Web support network. *Proceedings of the 1998 Annual International Conference of the Association for the Education of Teachers in Science*, Minneapolis, MN., United States. 47-49.

Boser, R. A. (1989). *The implementation of state-wide curriculum change in technology education: A summary of research report (ED314598).* Texas A & M University.

Bramble, W. J. (1980, January 16-18). The educational telecommunications Alaska project. *Proceedings of the National Conference on Professional Development and Educational Technology*, Washington, D.C., United States. 87-97.

Breiner, B. (2009). Creating tech wizards: Tech-savvy students help teachers transform practice. Learning & Leading with Technology, *36*(7), 24-27.

Buss, A. R., & McClug, P. A. (1999, March 29). *Initiating the use of GIS technology in Wyoming Public schools through in-service workshops* [Paper Presentation]. Annual Meeting of the National Association for Research in Science Teaching. Boston, MA., United States.

Bustamante, C. (2020). TPACK-based professional development on web 2.0 for Spanish teachers: A case study. *Computer Assisted Language Learning, 33*(4), 327-352. https://doi.org/10.1080/09588221.2018.1564333

Bybee, R. W., & Loucks-Horsley, S. (2000). Advancing technology education: The role of professional development. *The Technology Teacher, 60*(2), 31-34.

Carliner, S. (2013). How have concepts of informal learning developed over time? *Performance Improvement, 52*(3), 1-8. https://doi.org/10.1002/pfi.21330

Caverly, D. C., Peterson, C. L., & Mandeville, T. F. (1997). A generational model for professional development. *Educational Leadership, 55*(3), 56-59.

Chen, J. (2019). Restorying a "newbie" teacher's 3D virtual teaching trajectory, resilience, and professional development through action research: A narrative case study. *TESOL Quarterly, 54*(2), 375-403. https://doi.org/10.1002/tesq.550

Cheng, E. W. L. (2019). Choosing between the theory of planned behavior (TPB) and the technology acceptance model (TAM). *Education Technology Research & Development*, *67*, 21-37. http://doi.org/10.1007/s11423-018-9598-6

Chikasanda, V. K. M., Otrel-Cass, K., Williams, J., & Jones, A. (2012). Enhancing teachers' technological pedagogical knowledge and practices: A professional development model for technology teachers in Malawi. *International Journal of Technology & Design Education, 23*, 597-622. https://doi.org/10.1007/s10798-012-9206-8

Cleland, J. V., & Rilleo, P. (1996, January 11-14). Project SIMULATE: Technology staff development for inservice and preservice teachers. *Proceedings of the 1996 Annual International Conference of the Association for the Education of Teachers in Science, Seattle*, WA., United States. 363-379.

Coogle, C. G., Storie, S., Ottley, J. R., Rahn, N. L., & Kurowski-Burt, A. (2021). Technology-enhanced performance-based feedback to support teacher practice and child outcomes. *Topics in Early Childhood Special Education, 41*(2), 72-85. https://doi.org/10.1177/0271121419838624

Creswell, J. W., & Guetterman, T. C. (2019). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research, sixth edition.* Pearson Education.

Cuban, L. (1993). Computers meet classroom: Who wins? *Education Digest, 94(*7), 50.

Cuban, L. (2001). *Oversold and underused: Computers in the classroom*. Harvard University Press.

Curtin, P., Cochrane, L., Avila, L., Adams, L., Kasper, S., & Wubbena, C. (1994). A quiet revolution in teacher training. *Educational Leadership, 51*(7), 77-80.

Damewood, A. (2016). Current trends in higher education technology: Simulation. *TechTrends*, *60*, 268-271. https://doi.org/10.1007/s11528-016-0048-1

Darling-Hammond, L., & McLaughlin, M. W. (1995). Policies that support professional development in the era of reform. *Phi Delta Kappan, 95*(76), 597-604.

Delgado, A. J., Wardlow, L., McKnight, K., & O'Malley, K. (2015). Educational technology: A review of the integration, resources, and effectiveness of technology in K-12 classrooms. *Journal of Information Technology Education: Research*, *14*, 397-416.

Denton, J. J., & Manus, A. L. (1995). *Accountability effects of integrating technology in evolving professional development schools* [Research Report]. Educational Resources Information Center.

Dickman, C. B., Sickle, M. V., & Bogan, M. (1996, January 11-14). Integration and utilization of technology by secondary pre-service science teachers. *Proceedings of the 1996 Annual International Conference of the Association for the Education of Teachers in Science*, Seattle, WA., United States. 278-282.

Donoahue, Z. (2020). Action research by a classroom teacher: Professional development at its best. In K. Clausen & G. Black (Eds.), *The future of action research in education* (pp. 112-122). McGill-Queen's University Press.

DuFour, R., & Reason, C. (2016). *Professional learning communities at work TM and virtual collaboration: On the tipping point of transformation*. Solution Tree Press.

Duran, M., Brunvand, S., Ellsworth, J., & Sendag, S. (2012). Impact of research-based professional development: Investigation of inservice teacher learning and practice in Wiki integration. *Journal of Research on Technology in Education, 44*(4), 313-334.

Educational Technology Center. (1986). *Teacher as learner: The impact of technology* [Conference Report]. National Institution of Education.

Gill, D. D. (2019). A technology education teaching framework: Factors that support and hinder intermediate technology education teachers. *International Journal of Technology and Design Education*, *29*, 669-684. https://doi.org/10.1007/s10798-018-9465-0

Ginting, D., & Linarsih, A. (2022). Teacher professional development in the perspective of technology pedagogical content knowledge theoretical framework. *Jurnal Visi Ilmu Pendidikan, 14*(1), 1-10. https://doi.org/10.26418/jvip.v14i1.49334

Glatthorn, A. A. (1987). Cooperative professional development: Peer-centered options for teacher growth. *Educational Leadership, 45*(3), 31-35.

Glazer, E. M., Hannafin, M. J., Polly, D., & Rich, P. (2009). Factors and interactions influencing technology integration during situated professional development in an elementary school. *Computers in the Schools, 26,* 21-39. https://doi.org/10.1080/07380560802688257

Godfrey, C. (2013). *Barriers to the integration of educational technology in middle school classrooms: A study of teacher learning practices* [Unpublished master's thesis]. Nipissing University.

Goodnough, K. (2018). Understanding primary teachers' professional learning and practice: An activity theory lens. *Journal of Curriculum Studies, 51*(3), 362-383. https://doi.org/10.1080/00220272.2018.1488997

Goodyear, V. (2016). Sustain professional development on cooperative learning: Impact on six

teachers' practices and students' learning. *Research Quarterly for Exercise and Sport, 88*(1), 1-31. https://doi.org/10.1080/02701367.2016/1263381

Gurevich, I., Stein, H., & Gorev, D. (2017). Tracking professional development of novice teaches when integrating technology into teaching mathematics. *Computers in the Schools, 34*(4), 267-283. https://doi.org/10.1080/07380569.2017.1387470

Hall, A., & Trespalacios, J. (2019). Personalized professional learning and teacher self-efficacy for integrating technology in K-12 classrooms. *Journal of Digital Learning in Teacher Education, 35*(4), 221-235. https://doi.org/10.1080.21532974.2019.16447579

Harasim, L., & Johnson, M. E. (1986). *Educational applications of computer networks for teachers/trainers in Ontario*. Education and Technology Series. The Ontario Institute for Studies in Education.

Harris, J., Mishra, P., & Koehler, M. (2009). Teachers technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education, 41*(4), 393-416.

Hartsell, T., Herron, S. S., Fang, H., & Rathod, A. (2010). Improving teachers' self-confidence in learning technology skills and math education though professional development. *International Journal of Information and Communication Technology Education, 6*(2), 47-61. https://doi.org/10.4018/jicte.2010040105

Harvey, S., & Carpenter, J. P. (2020). Chapter 3: Genesis and change in physical educator's use of social media for professional development and learning. *Journal of Teaching in Physical Education, 39*, 445-453. https://doi.org/10.1123/jtpe.2019-0284

Hawkins-Sager, S. (1980, January 16-18). The "schools without schools": What it really taught us. *Proceedings of the National Conference on Professional Development and Educational Technology*, Washington, D.C., United States. 133-140.

Heinch, R. (1980, January 16-18). Implications of the expanding use of educational technology in education and training. *Proceedings of the National Conference on Professional Development and Educational Technology*, Washington, D.C., United States. 23-31.

Hennessy, S. (2014). *Bridging between research and practice: Supporting professional development through collaborative studies of classroom teaching with technology.* Sense Publishers.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development, 55*, 223-252. https://doi.org/10.1007/s11423-006-9022-5

Hixon, E., & Buckenmeyer, J. (2009). Revisiting technology integration in schools: Implications for professional development. *Computers in Schools, 26*, 130-146. https://doi.org/10.1080/07380560902906070

Hrastinski, S. (2008). Asynchronous & synchronous e-learning: A study of asynchronous and synchronous e-learning methods discovered that each supports different purposes. *Educause Quarterly*, *31*(4), 51-55.

Ince, M. L., Goodway, J. D., Ward, P., & Lee, M-A. (2006). Chapter 6: The effects of professional development on technological competency and the attitudes urban physical education teachers have toward using technology. *Journal of Teaching in Physical Education, 25,* 428-440.

Johnson, M. (2020). Training for the 21st century. *Midwest Quarterly*, *61*(3), 342-347.

Kanaya, T., Light, D., & McMillan Culp, K. (2005). Factors influencing outcomes from a technology-focused professional development program. *Journal of Research on Technology in Education*, *37*(3), 313-329.

Kelly, N. (2012, November). The information battlefield. *Training Magazine,* 10-12.

Kent, K. (1985). A successful program of teachers assisting teachers. *Educational Leadership, 43*(3), 30-33.

Kerr, S. T. (1989, February 1-5). Teachers and technology: An appropriate model to link research with practice. *Proceedings of Selected Research Papers Presented at the Annual Meeting of the Association for Educational Communications and Technology*, Dallas, TX., United States. 221-247.

Kimmel, H., Deek, F. P., Farrel, M. L., & O'Shea, M. (1999). Meeting the needs of diverse student populations: Comprehensive professional development in science, math, and technology for teachers of students with disabilities. *School Science and Mathematics Association, 99*(5), 241-248. https://doi.org/10.1111/j.1949-8594.1999.tb17482.x

King, K. (2002). Educational technology professional development as transformative learning opportunities. *Computers & Education*, *39*, 293-297.

Koch, J. (1996, January 11-14). Using e-mail partners in the elementary science methods course: A work in progress. *Proceedings of the 1996 Annual International Conference of the Association for the Education of Teachers in Science*, Seattle, WA., United States. 225-231.

Laitsch, D. (2020). Teachers as researchers and research users. In K. Clausen & G. Black (Eds.), *The future of action research in education* (pp. 99-111). McGill-Queen's University Press.

Lawless, K., & Pellegrino, J. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research, 77*(4). 575-614. https://doi.org/10.3102/0034654307309921

Lee, H., Longhurst, M., & Campbell, T. (2017). Teacher learning in technology professional development and its impact on student achievement in science. *International Journal of Science Education, 39*(10), 1282-1303. https://doi.org/10.1080/09500693.2017.1327733

Lemon, N., & O'Brien, S. (2019). Social media use in initial teacher education: Lessons on knowing where your students are. *Journal of Teacher Education, 44*(12), 38-56.

Liu, S-H. (2012). Teacher professional development for technology integration in a primary school learning community. *Technology, Pedagogy and Education, 22*(1), 37-54. https://doi.org/10.1080/1475939X.2012.71938

Lotherington, H. (2020). Learning to talk (dialogically) at school: Creating the discourse conditions for successful collaborative action research. In K. Clausen & G. Black (Eds.), *The future of action research in education* (pp. 33-47). McGill-Queen's University Press.

Loveland, T. (2012). Professional development plans for technology education: Accountability- based applications at the secondary and post-secondary level. *Technology and Engineering Teacher*, *71*(7), 26-31.

Martin, W., Strother, S., Beglau, M., Bates, L., Reitzes, T., & McMillan Culp, K. (2010). Connecting instructional technology professional development to teacher and student outcomes. *Journal of Research on Technology in Education, 43*(1), 53-74.

McEvoy, B. (1987). Everyday acts: How principals influence development of their staffs. *Educational Leadership, 44*(5), 73-77.

Meister, G. R. (1990). *Help for new teachers: Developmental practices that work*. Research for Better Schools.

Miller, D., & Glover, D. (2007). Into the unknown: The professional development induction experience of secondary mathematics teachers using interactive whiteboard technology. *Learning, Media and Technology,* 32(3), 319-331. https://doi.org/10.1080/17439880701511156

Mishra, C., Jung Ha, S., Parker, L. C., & Clase, K. L. (2019). Describing teacher conceptions of technology in authentic science inquiry using technological pedagogical content knowledge as a lens. *Biochemistry and Molecular Biology Education, 47*(4), 380-387. https://doi.org/10.1002/bmb.21242

Moltudal, S. H., Krumsvik, R. J., & Hoydal, K. L. (2022). Adaptive learning technology in primary education: Implications for professional teacher knowledge and classroom management. *Frontiers in Education, 7*, 1-18. https://www.frontiersin.org/articles/10.3389/feduc.2022.830536/full

Morris, M., Chrispeels, J., & Burke, P. (2003). Professional development that works - The power of two: Linking external with internal teachers' professional development. *Phi Delta Kappan, 84*(10), 764-767. https://doi.org/10.1177/003172170308401010

Mouza, C. (2003). Learning to teach with new technology: Implications for professional development. *Journal of Research on Technology in Education, 35*(2), 272-289.

National Science Board Commission on Precollege Education in Mathematics, Science and Technology. (1983). *A revised and intensified science and technology curriculum grades K-12 urgently needed for our future* [Conference Report]. National Science Foundation

Novick, R., & Grimstad, J. (1999). *Actual schools, possible practices: New directions in professional development*. Northwest Regional Educational Laboratory.

Olds Jr., H. F. (1981, January 11-16). How to think about computers. *Using computers to enhance teaching and improve teacher centers: A report of the National Teacher Centers Computer Technology Conference*, Houston, TX., United States. 13-29.

Paulus, M. T., Villegas, S. G., & Howze-Owens, J. (2020). Professional learning communities: Bridging the technology integration gap through effective professional development. *Peabody Journal of Education, 95*(2), 193-202. https://doi.org/10.1080/0161956X.2020.1745610

Pelavin Research Institute. (1998). *Professional development resource guide for adult educators: Building professional development partnerships project*. United States Department of Education.

Pennell, J. R., & Firestone, W. A. (1998). State-sponsored teacher-to-teacher professional development. *Education Digest, 63*(7), 354-357.

Prensky, M. (2001). Digital natives, digital immigrants. *On the Horizon, 9*(5), 1-6.

Randolph, J. (2009). A guide to writing the dissertation literature review. *Practical Assessment, Research, and Evaluation, 14*(13), 1-13. https://doi.org/10.7275/b0az-8t74

Rosaen, C. L., Hobson, S., & Khan, G. (2003). Making connections: Collaborative approaches to preparing today's and tomorrow's teachers to use technology. *Journal of Technology and Teacher Education, 11*(2), 281-306.

Rosenau, F. S. (1980, January 16-18). Educational database systems and the classroom teacher. *Proceedings of the National Conference on Professional Development and Educational Technology*, Washington, D.C., United States. 99-115.

Schmidt, M. E. (1997, February 14). *The effects of a 6 month professional development project on 5th and 6th grade teachers' beliefs and attitudes about calculators 2 years after the project* [Paper Presentation]. Annual Meeting of the Association of Mathematics Teacher Educators, Washington, D.C., United States.

Schmieder, A. (1981, January 11-16). Robots universal robots. *Using computers to enhance teaching and improve teacher centers: A report of the National Teacher Centers Computer Technology Conference,* Houston, TX., United States. 7-11.

Schrock, K. (2012). Equipping teachers to infuse technology. *District Administration, 48*(1), 57-63.

Schrum, L. (1991). Teacher education goes online. *Educational Leadership, 49*(3), 39-42.

Shaka, F. L. (1998, January 8-11). Stimulating professional growth of teachers through action research. *Proceedings of the 1998 Annual International Conference of the Association for the Education of Teachers in Science*, Minneapolis, MN., United States. 565-572.

Sheffield, R., Blackley, S., & Moro, P. (2018). A professional learning model supporting teachers to integrate digital technologies. *Issues in Educational Research, 28*(2), 487-510.

Sherman, T., Sanders, M., & Kwon, H. (2010). Teaching in middle school technology education: A review of recent practices. *International Journal of Technology and Design Education, 20,* 367-379. https://doi.org/10.1007/s10798-009-9090-z

Stager, G. S. (1995). Laptop schools lead the way in professional development. *Educational Leadership, 53*(2), 78-81.

Symons D., & Pierce, R. (2019). Programs, packages, and apps: Some guidance for investment in technology. *Australian Primary Mathematics Classroom*, *24*(1), 3-6.

Tan, T., Calmer, J., & Recinos, R. (2019). Matching technology with teachers to improve and accelerate learning: Unleashing the benefits of teaching and learning using technology requires growth of technology availability in the classroom and growth in how those technologies are used. *Leadership*, *48*(4), 28-33.

Vrasidas, C., & Glass, G. V. (2007). Teacher professional development and ICT: Strategies and models. *Yearbook of the National Society for the Study of Education, 106*(2), 87-102. https://doi.org/10.1111/j.1744-7984.2007.00116.x

Wildman, T. M., & Niles, J. A. (1987). Essentials of professional growth. *Educational Leadership, 44*(5), 4-10.

Wilkerson, M. H., Andrews, C., Shaban, Y., Laina, V., & Gravel, B. (2016). What's the technology for? Teacher attention and pedagogical goals in a modeling-focused professional development workshop. *Journal of Science and Teacher Education, 27*, 11-33. https://doi.org/10.1007/s10972-016-9453-8

ABOUT THE AUTHOR

Christopher Godfrey: A doctoral candidate at the Schulich School of Education at Nipissing University, he has spent more than a decade teaching K-12 students in the Canadian public and private educational systems. He is also proud to have crafted walking tour experiences for students from around the globe. Christopher's work in action research focuses on restoring teacher voice in professional learning, creating opportunities for educators that better serve their needs, wants, and unique classroom environments. He was recently honoured by The Learner Network, receiving their prestigious *Emerging Scholar Award* in 2021.