Fostering a Technology-rich Professional Learning Community: A Design-based Research Cycle

Lei Nong, Alain Breuleux, & Gyeong Mi Heo
McGill University, QC, Canada
lei.nong@mail.mcgill.ca

Abstract: This paper describes the early process of a teacher professional development project during which a technology-rich professional learning community was developed and refined to support ongoing teacher development. The aim of this project was to improve teachers' digital literacy and disciplinary understanding in the mathematics classroom, with a focus on student learning in the transition from elementary to secondary schools. The results indicate that this learning community fostered a shared vision of continued development among teachers. Teachers shared their experience of practice and supported each other's learning to improve student learning. In addition, they explored the effective use of digital tools for student learning in the classroom.

Introduction

This study responds to the real concerns for improving teachers' effective use of technology and disciplinary understanding in the mathematics classroom, with a focus on supporting students' mathematic learning in the transition from elementary to secondary schools. To address these challenges, a group of university researchers and school experts create a teacher professional development (PD) project to support teachers' ongoing development. The goal of this project is to develop and sustain a supportive technology-rich professional learning community (PLC) that helps teachers to improve their practice through the iterative design and validation of such PLC. This case study focuses on describing the unfolding of the early phase of this project during which the technology-rich PLC was designed, implemented, and refined. In specific, we examine the following question:

How did the processes of design, implementation and refinement of the technology-rich PLC unfold in the early stages of this PD project?

Conceptual Background

Digital competence and ongoing teacher learning

In recent years, teachers have been introduced to a variety of digital technologies. While more and more teachers have embraced the idea of teaching with digital technology and tried some of these tools in their classroom, high-level use of technology is still relatively rare (Lawless & Pellegrino, 2007). Many researchers criticized that traditional teacher training activities (e.g., workshop, educational technology courses) emphasize primarily how to use technology tools and neglect the perspective of how technology is used to support pedagogy, especially content-specific pedagogy (Angeli & Valanides, 2009; Mishra & Koehler, 2006). Zhao et al (2002) argue "teachers need to know the affordance and constraints of various technologies and how specific technologies might support their own teaching practices and curricular goals" (p.511). In addition, the short duration of these PD activities is often unable to provide follow-up, long-term support to teachers (Zhao et al., 2002).

Similar concern of insufficient high-level technology use is also reported in math education (Niess, 2005). However, research on supporting teachers' effective technology use in the math classroom -especially research on the transition between elementary and secondary school- is still limited. To improve teachers' digital literacy as well as disciplinary understanding in the mathematics classroom, we adopted the model of professional learning community (PLC) in this project to engage teachers in ongoing development of their practice. A PLC is generally viewed as an innovative form of PD that brings teachers and other educational practitioners together to share and interrogate teachers' practice in a collaborative, ongoing, and reflective way (Stoll, Bolam, McMahon, Wallace & Thomas, 2006). We chose the PLC model because of its potential to promote professional learning for teachers (Bolam et al., 2005; Stoll & Louis, 2007).

Nong, L., Breuleux, A., & Heo, G. M. (2015). Fostering a technology-rich professional learning community: A design-based research cycle. In D. Slykhuis & G. Marks (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2015* (pp. 1236-1244). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Furthermore, we adopted a design-based research approach (Brown, 1992; Collins, 1992) to frame the design and validation of this PLC. Design-based research emphasizes using a set of learning theories deliberately to design learning environments that could be applied to real-life settings, and updating the learning environments when needed after the systematic examination of learning within those contexts (Barab & Squire, 2004). This character of design-based research results in a cyclical system of learning environment design (Plomp, 2013, see Figure 1) which allow us to design and maintain the PLC in an effective and sustainable way. Based on identified problems, we first analyzed target context and a relevant learning theory (i.e., the model of PLC) for the project. In the second step, we used those predetermined learning principles to develop a concrete product –a prototype PLC– that can be used in the target context. The third step was to evaluate teachers' learning to examine the prototype in implementation. Lastly, we revised the current prototype when its implementation revealed limitations or when new problems from the target context emerged. In particular, this paper focuses on the process of the first design-implementation-revision cycle of the project.

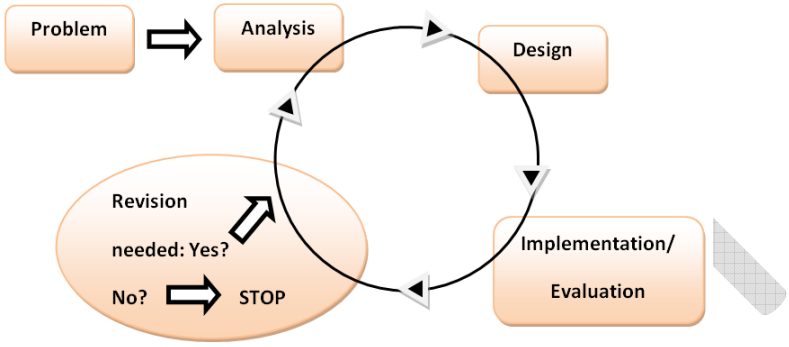

Figure 1. Iterations of systematic cycles (adapted from Plomp, 2013).

The underlying learning principles of the PLC

We identified four principles of the PLC in this project. First, we aimed at fostering a coherent vision among teachers. The shared vision is a preferred picture of the future which directs what PLC members work toward (Stoll et al., 2006). By sharing common values and goals, members in the PLC would determine what problems they will solve and how to work together. It was assumed that such shared vision could foster teachers' collective commitment toward ongoing development within the community.

Second, we tried to engage teachers in collaborative learning through sharing practice and reflective inquiry. In the PLC, we would encourage teachers to share their practice with others, including issues such as students' difficulties, teaching strategies, and evaluation process. Such sharing is not to judge others, but to be critical of their own practices as well as others (Hord, 2004; Stoll et al., 2006). This is valuable to prompt their own learning as well as those of others and improve their practice for the benefit of students. Increasingly, teachers were expected to trust each other and welcome different perspectives from colleagues.

Third, effective PLCs require supportive conditions (Hord, 2004; Stoll et al., 2006). Whether a PLC could function productively depends on appropriate support. Hord (2004) identified two types of support: a) human capacities, and b) physical factors. Human capacities refer to support from the educational experts in schools and other external organizations. Physical factors might encompass the availability of learning resources, time for professional development, and technology supports. In our case, both internal and external experts were included in this PLC as human capacities to support effective teacher learning. The internal experts included one associate director of pedagogical services and three school consultants from the participating school board. The external experts comprised three university researchers. These experts formed a leadership team to plan, implement, and analyze the process of the project, and to scaffold teacher learning during PD activities. Another responsibility of the leadership team was to provide needed physical support (e.g., arranging release time for teachers to participate in PD activities, offering learning and teaching resources to teachers).

Fourth, this PLC not only prepared teachers to teach with technology thoughtfully, but also immersed them in a technology-rich learning environment. In other word, teachers would explore the use of new technology tools

Nong, L., Breuleux, A., & Heo, G. M. (2015). Fostering a technology-rich professional learning community: A design-based research cycle. In D. Slykhuis & G. Marks (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2015* (pp. 1236-1244). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

that could be used in their classroom, and also use digital tools in their own learning. Inspired by the work of Mishra and Koehler (2006), we used the idea of technological pedagogical content knowledge (TPACK) to guide our introduction of technologies to teachers and for the integration of technology in PD activities. Mishra and Koehler (2006) argued that the relationship among content, pedagogy, and technology is interactively related, each element providing both affordances and constraints to the other two. In practice, teachers need to develop content-specific teaching strategies with appropriate technologies. They further proposed the approach of *learning technology by design* to foster teachers' awareness of such relationship (i.e., knowledge of TPACK). This method posits that the experience of technology learning needs to be situated in the authentic problems of practice that allow teachers to think about how technology could be designed, used, and revised in solving those problems. By engaging teachers in sustained technology design and revision for practice, it is assumed that teachers will gain a deep understanding of technology use in the classroom. From the perspective of the leadership team of this project, we used TPACK to reflect on what digital tools can be used effectively, and how to promote teacher development.

Inquiry

To validate the reliability of the research, one aim of design-based research is to lay open the completed design and implementation of learning environment (Barab & Squire, 2004). This often relies on techniques such as collecting a large range of data sources, systematic analysis of data with pre-defined measures, and a thick description to the process of design and implementation (The Design-Based Research Collective, 2003). Therefore, the method of descriptive case study (Yin, 2009) was employed in this study to present how the PLC design and implementation process unfolded in the early stages of this project.

Participants

Thirteen mathematics teachers from an English school board in the Montreal area enrolled in the project. Seven participants were Grade 6 math teachers, and the others were teachers who taught Grade 7 math in secondary schools. All teachers were recruited by the consultants from the school board, in seven elementary schools and four secondary schools within the school board. Their teaching experience ranged from 2 to 19 years. The duration of the first research cycle was approximately eight months, from August, 2013 to March, 2014.

Data Collection and Analysis

The study drew from various sources of data from the project database, consisting of five types of data: a) documents including the proposal, the agendas of leadership meetings and PD face-to-face meetings, and a periodic report that summarized previous PD activities; b) the field notes of PD face-to-face meetings and leadership meetings; c) artifacts from face-to-face meetings; d) a transcript of the leadership meeting (debriefing meeting); and e) the log files of teachers' online posts (e.g., textual posts, video posts, and website links).

The primary methodology used in data analysis was thematic analysis, because it allows researchers to use a theory-driven approach to analyze a wide variety of information in a systematic manner (Boyatzis, 1998). Corresponding to the design-implementation-revision phases of a prototyping cycle, three major themes were generated. These three respectively described how the concrete PLC was designed from the "abstract" proposal, how the initial design was implemented and evaluated, and how the design was refined based on the evaluation of teacher learning.

Results: The Implementation Process

Design Phase

From the project proposal, the leadership team determined an overall goal of fostering a technology-rich PLC to support teacher learning and teaching in the early cycles of the project. This goal was crucial in creating a culture of professional learning that set the foundation for future PD activities. The next step was to develop detailed objectives and elaborate the learning principles embedded in these objectives (see Table 1). Specifically, three objectives were pursued.

Table 1

The Design Process from Proposal to Activities

Overall goal	Objectives	Embedded learning principles	Concrete activities	Anticipated learning processes
Foster a technology-rich PLC	Developing a collective understanding of the situation	Shared vision and responsibility	Introduction to the project. Activities at face-to-face meetings • Sharing successful strategies in the classroom (1st meeting) • Discussion of technology-related practice (2nd meeting) • Challenging concepts for students (3rd meeting)	Teachers had a collective understanding of situation and developed shared goals that they need to work toward (i.e., supporting student success in the elementary-secondary transition and developing effective technology use in the classroom.)
	Sharing, inquiry and reflection	Sharing practice and reflective inquiry	Activities at face-to-face meetings: • Sharing successful strategies in the classroom (1st meeting) • Discussion of technology-related practice (2nd meeting) • Challenging concepts for students (3rd meeting) Edmodo discussion	Teachers opened their practice to dialogue and engaged in the activities of sharing, inquiry, and reflection.
	Developing the use of digital tools for teachers and students	The notion of TPACK and the approach of *learning technology by design*	Activities at face-to-face meetings • Designing video lessons (1st meeting) • Creating mini-lessons using digital tools (3rd meeting) EdModo discussion	First, teachers used digital tools for their own learning. Second, teachers explored the use of digital tools and integrated these digital tools in their classrooms for student learning.
	Supportive conditions[1] ① human capacity: the CCC-M learning environment involved internal supports from the school experts and external supports from the research team. ② physical support: the CCC-M project arranged release time for teachers to participate in PD activities; offers learning resources to teachers; and provided teaching materials and devices that teachers required in the classroom.			

- Developing a collective understanding of the situation: in order to identify the collective goals of learning within the community, teachers needed to be aware of their communal challenges and get to know others' situation of practice. Thus the leadership team planned a set of ongoing dialogues for teachers to develop and strengthen a collective understanding of the situation.

[1] Support conditions were not identified as the objective for teacher learning, but it was viewed as a key learning principle that supported the effectiveness of the CCC-M learning environment.

Nong, L., Breuleux, A., & Heo, G. M. (2015). Fostering a technology-rich professional learning community: A design-based research cycle. In D. Slykhuis & G. Marks (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2015* (pp. 1236-1244). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

- Sharing, inquiry, and reflection: the PD activities were organized in ways that tried to promote teacher learning through reflective inquiry.
- Developing the use of digital tools for teachers and students: guided by the notion of TPACK, the leadership team tried to select optimal digital tools to support effective teacher learning. Moreover, the leadership team identified several potential digital tools that teachers could use in their classroom for student learning. The introduction of digital tools was embedded in the activities that required teachers to design the use of digital tools for their practice.

Based on these three objectives, the leadership team developed a series of concrete PD activities for the first research cycle. There were two types of PD activities: activities at face-to-face meetings and online discussions on Edmodo.

The face-to-face meetings were viewed as a crucial component of PLC to develop a collegial relationship among teachers. Moreover, the leadership team used these meetings to introduce new ideas and help teachers to know what learning looked like in the PLC. Three face-to-face meetings were planned and a set of activities were included.

Due to the busy schedule of teachers, the leadership team also planned to use Edmodo[2] as a platform to create asynchronous learning opportunities for teachers between face-to-face meetings. Teachers were asked to post on Edmodo weekly between face-to-face meetings. The posts could be reviewing the experience in the classroom, sharing learning and teaching materials, and responding to others' posts. The leadership team also joined in the online learning group to provide support for teacher learning.

Implementation Phase[3]

Face-to-face PD activities. The first face-to-face meeting took place in the early Fall semester. After an introduction to the project, the first activity was a sharing activity that asked teachers to share their successful strategies in the classroom. The reason for planning this activity was to use non-threatening conversation to encourage teachers to open their practice. In the afternoon, the leadership team introduced the use of short video lesson as complementary teaching materials. Following a presentation of video lesson, the leadership team grouped teachers into pairs and then asked them to create an instructional video of a math concept they would like to teach. After teachers completed their videos, they were asked to share their artifacts with teachers in another group. Teachers in that group acted as students to watch the video and gave feedback.

The second face-to-face meeting took place at the end of the Fall semester after teachers had time to apply some ideas they had learned from the first face-to-face meeting. The principal goal of this meeting was to guide teachers in the activity of sharing, inquiry and reflection. The leadership team asked teachers to reflect on their technology-related experiences, share with their colleagues, and ask questions to others' sharing. The topic of experience sharing could be any interesting resource, strategy used, observation of their class, challenge, and suggestion of improvement.

The third face-to-face meeting took place in the early Winter semester. This meeting moved teachers to the activities that combined the elements of pedagogy, technology, and specific contents. In the morning, the leadership team engaged teachers to share those contents that students struggled with. The technology consultant from the leadership team then demonstrated the use of some math tools on the interactive white board (IWB)[4]. After that, she required teachers to work in groups (three or four teachers from the same level), using the IWB math tools to create a mini lesson for one of the struggling concepts. One or two of the teachers in each group were responsible for

[2] Edmodo was chosen because it is a specialized educational online social network that enables its users to create online learning groups. Teachers could set up learning groups, posting learning information (e.g., sharing their experience in the classroom, uploading the attachments of learning and teaching materials, posting links to educational websites) and commenting on others' posts. Besides, Edmodo was recommended to teachers as an online learning platform with their students. Teachers could create learning group for each of their classes.

[3] Due to the limitation of this short paper, the detailed analyses of teacher learning are not presented here. For a more complete account, please see Nong (2014).

[4] The IWB math tools were introduced because more and more classrooms in the school board had equipped with IWBs and some of the participating teachers had already used IWBs in their classroom.

carrying out their mini lesson in the afternoon. The rest of teachers asked questions and gave feedback after the lesson was taught.

Gradually, teachers' discussion moved from sharing of general teaching strategies to conversations on students' content-specific problems. In the beginning, teachers only shared the general strategies they thought successful. At the third face-to-face meeting, teachers had an extensive discussion of the concepts that student struggled with. They found that many mathematics concepts were the same in the curricula of late elementary and early secondary grades. And they were very surprised to realize that their students had similar, repeated difficulties, even across two grades. These understandings raised questions as to why student had difficulties in such areas. They were also wondering why students who seemed to master mathematics concepts in Grade 6 did not do well in Grade 7.

Moreover, teachers were able to discuss thoughtfully about the strategies or technology use according to individual needs and student learning. At the second face-to-face meeting, one teacher reflected that one of her classes did not like the idea of watching video lessons. Her students expected her to explain mathematics concepts face-to-face, so she did not give video lessons to this class. Another teacher extended the use of video lessons as an evaluation tool. She asked her students to create video lessons explaining the math concepts they had learned as teachers did. She used these students' videos to assess their understanding of math concepts.

Online discussion on Edmodo. All teachers participated in online discussion. Technology-related posts dominated teachers' online discussions, especially posts about teachers' attempts to use technology in their classroom. Most teachers shared their experiences of trying to incorporate the ideas learned from face-to-face meetings (e.g., the use of video lesson, and using Edmodo with students) and from other teachers. Some teachers further discussed the problems that emerged in their classroom when implementing these ideas or digital tools. One example came from Dave. He reported that he created two Edmodo learning group for his two classes, but only one of his classes used it actively. In addition, several teachers posted their reflection on technology use, they elaborated on why they use specific digital tools for specific contents and those tools help student learning. For instance, Mary explained why she chose an iPad app according to her students' difficulties with breaking down numbers.

In support of other teachers' learning, some teachers shared their learning and teaching materials. Besides, they posted information about digital tools that they thought useful in the classroom. Some of these materials and digital tools were adopted by other teachers in the PLC.

In general, many of the teachers were able to learn new ideas from others and apply other's ideas in their own classrooms. Nevertheless, several shortcomings emerged from the online discussions by teachers. First, most posts from teachers were quite brief, especially when sharing their experience in the classroom. The general pattern of experience sharing was: "what I have done in the classroom" plus "whether student liked it or not". There was limited discourse to reason why such teaching strategies or digital tools were used and how these strategies or digital tools help student learning. Second, there were important differences across teachers' use of Edmodo. Some teachers were more active on Edmodo, while a few teachers barely posted.

Revision Phase

Not long after the third face-to-face meeting, the leadership team had a debriefing meeting. Based on the evaluation of teacher learning, the leadership team maintained the use of the predetermined PLC model in the design of the next research cycle, but identified several revisions to refine the PLC activity design.

To strengthen a collective understanding the situation, the updated design of activities would provide more opportunities for teachers to investigate those common mathematics contents that student struggled with. Also, the leadership team planned opportunities for teachers to visit each other's classroom. The leadership team hoped that this activity could help teachers to explore learning and teaching from a different perspective as observers, and focus on details of student learning process.

Moreover, there was still a lack of in-depth dialogue of reflective inquiry. Teachers' conversations were mainly about describing experience and sharing information (especially the online discussions). One explanation was that teachers lacked opportunities to see how to dig into their teaching as well as student learning systematically. Consequently, the activities in the next cycle would provide teachers with guidance for reflective

inquiry. The initial plan was to identify a theoretical model of reflection to guide the reflective learning activities for teachers.

Finally, the limited use of Edmodo required the leadership team to identify a way to foster teacher online learning. The primary idea was to ask teachers their opinions on effective Edmodo use in order to plan more effective ways to foster learning activities on Edmodo.

Interpretation

The results suggest that teachers had gradually developed a collective understanding of the situation. They realized that there were similarities and differences in learning and teaching between elementary and secondary levels. More importantly, they recognized the importance of communication and of a collective commitment to understand and support students' mathematics learning in the elementary-secondary transition. They started to request more collaborative learning opportunities to investigate the situation of learning in others' classroom.

Second, participating teachers were able to take an active stance to embrace new ideas from their colleagues and the leadership team. They showed a good attitude to share their practice and support others' learning. However, more in-depth dialogues of reflective inquiry are still needed for online discussion.

Third, teachers had developed the use of different digital tools in their classroom for students. Teachers showed a great enthusiasm to try out new technology tools and share their uses with their colleagues. Some of teachers had already shared their perception of effective technology use. These teachers deliberately used different technology tools according to student learning needs. Moreover, activities during the face-to-face meetings gave teachers a sense that their adoption of digital tools needed to consider how these tools met their instruction, curriculum, and local situation. By contrast, teachers did not take full advantage of technology use for their own learning. The online discussion on Edmodo was less productive compared to those at the face-to-face meetings.

Implications and Further Research

The culture of PLC

For many years, researchers have suggested the importance of teacher communication and collaboration in teacher continued learning and practice (Hord, 2004; Lieberman & Wood, 2000; Little, 1982). Nevertheless, the isolation between teachers is still a reality. Teachers do not have enough chances to communicate with their colleagues. This project created a PLC to provide elementary and secondary teachers with a collective learning opportunity to explore their shared challenges. Again, the norm of teachers' collegiality within this PLC was not to blame others for the problem, but to enhance their teaching practice of supporting students' learning collectively. Obviously the participating teachers have recognized the norm and the value of collaborative learning. They asked for more opportunities to communicate with their colleagues in the community and even other teachers from outside. An implication for future research is to scale up this project into school-wide initiatives to open the dialogue between more teachers.

The culture of PLC not only fostered a shared vision among teachers to encourage continued development, but also provided a supportive affordance to improve teachers' effective use of technology in the classroom. The notion of TPACK emphasizes the convergence of technology, pedagogy, and content by situating teachers' exploration of technology tools in their practice (Angeli & Valanides, 2009; Mishra and Koehler, 2006). This idea is consistent with the tenet of PLC that the growth of practice is best achieved through situated learning in the context of practice (Leithwood, Jantzi, & Steinbach, 1998). The integration of technology learning in teachers' practice, especially in addressing their shared problem, enabled teachers to see how technology tools can be used productively to improve their practice.

Lessons learned from the PLC development

When developing this PLC, there were two important lessons learned from our first research cycle. First, the collaboration between university researchers and school experts was a key to our PLC design and implementation. In this project, school experts brought the real learning problem of students that the school board and teachers wanted to address together with their expertise of working with teachers; while university researchers provided theoretical grounding to the learning environment design as well as data collection and analysis processes. This partnership is crucial to ensure the applicability of the PLC. Second, the effectiveness of the PLC required constant design, reflection, and revision. Teacher professional development in such authentic contexts involves complex learning activities affected by many factors. During the implementation of the PLC, not every expectation was met and new problems emerged. The approach of design-based research allowed us to plan ahead; thinking about how to design the PLC, to examine teacher learning in practice, to reflect on the design and the implementation of the PLC, and to seek improvement in a coherent and systematic manner.

References

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education*, *52*(1), 154-168.

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, 13(1), 1-14.

Bolam, R., McMahon, A., Stoll, L., Thomas, S., Wallace, M., Greenwood, A., & Smith, M. (2005). *Creating and sustaining effective professional learning communities*. Research Report 637. London: DfES and University of Bristol.

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA: Sage Publications.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The journal of the learning sciences*, *2*(2), 141-178.

Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New directions in educational technology* (pp. 15-22). New York, NY: *Springer* Verlag.

Hord, S. M. (Ed.). (2004). *Learning together, leading together: Changing schools through professional learning communities*. New York, NK: Teachers College Press.

Lawless, K. A., & Pellegrino, J. W. (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.

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *The Teachers College Record*, *108*(6), 1017-1054.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509-523.

Nong, L. (2014). *Fostering a Technology-rich Professional Learning Community: A Design-based Research Cycle* (Unpublished Master's thesis). McGill Unviversity, Montreal.

Plomp, T. (2013). Educational design research: An introduction. In Plomp, T. & Nieveen, N. (Eds.), *An introduction to educational design research* (pp. 10-51). Enschede: Netherlands Institute for Curriculum Development (SLO).

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of educational change*, *7*(4), 221-258.

Stoll, L., & Louis, K. S. (2007). Professional learning communities: Elaborating new approaches. In *Professional learning communities: Divergence, depth and dilemmas*, 1-13.

Nong, L., Breuleux, A., & Heo, G. M. (2015). Fostering a technology-rich professional learning community: A design-based research cycle. In D. Slykhuis & G. Marks (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2015* (pp. 1236-1244). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

The Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 5-8.

Yin, R. K. (2014). *Case study research: Design and methods*. Thousand Oaks, CA: Sage Publications.

Zhao, Y., Pugh, K., Sheldon, S., & Byers, J. (2002). Conditions for classroom technology innovations. *The Teachers College Record*, *104*(3), 482-515.

Nong, L., Breuleux, A., & Heo, G. M. (2015). Fostering a technology-rich professional learning community: A design-based research cycle. In D. Slykhuis & G. Marks (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2015* (pp. 1236-1244). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).