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The Professional Learning of Grade Six Teachers of Mathematics Implementing the Flipped Classroom Approach

Le perfectionnement professionnel des enseignants de mathématique en 6e année mettant en œuvre l'approche de la classe inversée

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Abstract

The purpose of this paper is to make sense of the professional learning of four teachers implementing a flipped classroom approach in their grade six mathematics class. The professional learning took place within a two-year Action Research (AR) project that engaged teachers in collaborative and iterative planning, implementation, observation and reflection. Data collection relied on semi-structured interviews, teachers' reflections, plans of action, and final multimedia artefact. Post-project data analysis relied on a framework adapted from workplace and organizational learning. The findings revealed that teachers with varying levels of subject-area expertise, comfort with technology, and experience with teaching improved their practice by expanding their community and their tools to become designers of learning. Future studies may investigate issues of sustainability and feasibility of teachers' professional learning supported by AR, and with the flipped approach to determine which tools may be more essential than others. Implications highlighted the difference between K-12 versus post-secondary implementation of the flipped approach in relation to parental involvement.

Résumé

L'objet de cet article est de saisir la signification du perfectionnement professionnel de quatre enseignants mettant en œuvre l'approche de la classe inversée dans leur cours de mathématique en 6e année. Le perfectionnement professionnel s'est déroulé durant un projet de recherche-action de deux ans au cours duquel les enseignants ont pris part à une planification collaborative et itérative, à une mise en application, à de l'observation et à une réflexion. La collecte de données s'est basée sur des entrevues semi-structurées, sur les réflexions des enseignants, sur des plans d'action et sur les artefacts multimédias finaux. L'analyse des données post-projet s'est appuyée sur un cadre adapté issu de l'apprentissage en milieu de travail et de l'apprentissage organisationnel. Les conclusions révèlent que des enseignants ayant différents

niveaux d'expertise dans leur discipline, d'aisance avec la technologie et d'expérience en enseignement ont amélioré leur pratique en enrichissant leur collectivité et leurs outils pour devenir concepteurs de l'apprentissage. De futures études pourraient se pencher sur les questions de la durabilité et de la faisabilité du perfectionnement professionnel des enseignants appuyé par la recherche-action, ainsi que sur l'approche inversée pour déterminer quels outils sont les plus essentiels. Les implications ont souligné la différence de mise en œuvre de l'approche inversée de la maternelle à la 12e année comparativement à sa mise en œuvre en contexte postsecondaire relativement à la participation des parents.

Introduction

This paper reports on the professional learning of four, grade six teachers of mathematics. Their learning took place in a context of an Action Research (AR) project and use of the flipped classroom approach. The AR involved teachers engaging in two cycles of collaborative and iterative planning, implementing (acting), observing, and reflecting (Kemmis & McTaggart, 2000). The underlying principle on which the AR was premised was that of a collaborative concern to bring about change in the culture of teachers' practice (see McTaggart, 1997). Post project, we analysed teachers' learning to portray it using a framework of four questions related to who was learning and why, how, and what they were learning. The framework supported making sense of teachers' learning as they engaged in AR and the flipped classroom approach. Making sense is important in terms of how the flipped classroom approach can support teachers' professional learning through both understanding and building knowledge about it.

The Flipped Approach

There are numerous accounts of the history of the flipped approach (e.g., Coufal, 2014), its theoretical underpinnings (e.g., Bishop & Verleger, 2013), its benefits and challenges (e.g., Mazur, Brown, & Jacobsen, 2015) and reactions by students to its use (e.g., Galway, Berry, & Takaro, 2015). In general, however, the literature on the approach is largely dominated by empirical studies of post-secondary students' experiences (e.g., Blair, Maharaj, & Primus, 2015) along with instructors' anecdotal accounts (e.g., Enfield, 2013). Empirical reports of K-12 teachers' professional learning with the approach are virtually absent in the literature. Yet, as Howitt and Pegrum (2015) argued, "it is timely that research is conducted from teachers' perspectives" (p. 461).

Flipping involves a form of blended learning in which face-to-face (F2F) teachers' transmission of content is replaced by online access. Taking the transmission out of the classroom through reliance on Information and Communication Technologies (ICTs) frees up classroom time so that teachers can engage students in more active forms of learning. In general, flipped classrooms are pedagogical approaches:

> ... in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter. (Yarbro, Arfstrom, & McKnight, 2014, p. 5)

While the approach remains "under-evaluated, under-theorised and under-researched," it has been associated with active learning and motivation (Abeysekera & Dawson, 2015, p. 2), along with problem-based learning and peer-assisted learning (Franqueira & Tunnicliffe, 2015). In relation to professional learning, the flipped approach is a tool that teachers can use for "pedagogical redesign" (Howitt & Pegrum, 2015), since its implementation requires an overall "shift in the learning culture" (Ng, 2015, p. 152). It can support a move from teacher to student-centredness (Hamdan, McKnight, McKnight, & Arfstrom, 2013) and from direct instruction to "a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" (Yarbro et al., 2014, p. 5).

Hamdan et al. (2013) outlined some of the complex requirements for educators who want to adopt the approach. They must "determine when and how to shift direct instruction from the group to the individual learning space, and how to maximize the face-to-face time between teachers and students" (p. 5-6). They must observe and assess continuously, reflect on practice, offer feedback and "connect with each other to improve their trade..." (p. 6). Howitt and Pegrum (2015) posited that, "to successfully implement a flipped approach, teachers have to design, or redesign, the overall structure of learning" (p. 460).

The Present Study

Learning to design, or redesign, the structure of learning is highly complex. In this paper, we aim to make sense of that complexity in a unique context of AR that, as McTaggart (1997) explained, is designed to change not only individual teachers, but also their practice. Four teachers of grade six mathematics (two females and two males) volunteered to participate in the study that took place over a two-year period, representing two AR cycles. However, one of the four teachers joined the study in year two.

Making sense of this type of professional learning is challenging because engaging in AR does not involve simply acquiring what Engeström referred to as "identifiable knowledge or skills" that are "stable and reasonably well defined" (2001, p. 137). Teachers were not merely being taught a new technique; rather they were engaged in AR which, as McNiff and Whitehead (2010) explained, is "a methodology for social and cultural change" (p. 2). To make sense of their learning we conducted a post-project analysis using a framework adapted from workplace and organizational learning contexts (e.g., Engeström, 2001). The framework focuses attention on the professional learning through a lens of four questions as follows:

1. Who is learning?
2. Why do they learn?
3. How do they learn?
4. What do they learn?

Our focus on teachers' professional learning responds to Mazur, Brown, and Jacobsen's (2015) call for further investigations into "implementation of flipped classroom instruction in kindergarten to grade twelve classrooms" (p. 15). In this case, however, we are focusing specifically on how the *teachers* are learning.

Literature Review: The Flipped Classroom and AR

Our literature review is limited to studies of the flipped approach in the context of professional learning with AR. There are numerous empirical reports of the flipped approach in the mathematics classroom (e.g., Triantafyllou & Timcenko, 2015) but these do not provide insights into how *teachers* learn by implementing the flipped approach. Our review uncovered few studies of the flipped approach in contexts of professional learning using AR. Table 1 provides an overview of those we identified.

Table 1

Overview of Studies

Study	Subject area	Location	Participants	Level
Mazur et al. (2015)	Social studies	Canada	Educator/ researcher	Grade 9
Clark (2015)	Mathematics (algebra)	USA	1 instructor	Secondary
Danker (2015)	Performing arts course	Malaysia	1 instructor	Post-secondary
Lintern, Davies, McGinty, & Fisher (2014)	Psychology course	North Wales	1 student teacher	Post-secondary
MacKinnon (2015)	Introductory science teacher education course	Canada	1 instructor	Post-secondary
Kenny & Newcombe (2014)	Undergraduate educational psychology course	USA	1 instructor	Post-secondary undergraduate
This study	Mathematics	Canada	4 in-service teachers	Grade 6

The studies highlighted learning that is inquiry-based (MacKinnon, 2015; Mazur et al., 2015), interactive and deep (Danker, 2015), student-centred (Clark, 2015; Lintern et al., 2014), constructivist (MacKinnon, 2015), and active (Kenney & Newcombe, 2014; Lintern et al., 2014; Mazur et al., 2015). At the same time, in some studies, these approaches were driven by a need to address a specific problem. Mazur et al. relied on the approach to "maximize instructional time" (p. 3) in order to be able to implement inquiry-based, active student learning. The approach also represented a means to integrate educational technology as part of government initiatives to redesign curriculum to promote student engagement. Likewise, Danker needed to address the problem of a sudden increase in class size that made it difficult for instructors to engage students, and left them little time for individualized attention. Like Mazur et al., Lintern et al. relied on the flipped approach as a means to satisfy learners' unmet expectations of technology. Clark's study involved using the approach to address the problem of passive learning in mathematics, while

Kenny and Newcombe were looking for alternative approaches to address this same problem of passive learners. Likewise, our study took place in a context of helping teachers learn to improve their practice by engaging in inquiry.

Only one of the studies focused on mathematics (Clark, 2015), and it reported on findings related to students' learning. Students' learning is not the object of our inquiry. None of the studies focused on the elementary level. With the exception of Mazur et al. (2015), the studies represented instructors' reports of how they themselves relied on AR to engage in cycles of planning, design, and implementation of the approach. Mazur et al. (2015) did not collect data directly from the participating teachers, rather, the educator/researcher reported on her reflections of working with the teachers and was guided by a Teaching Effectiveness Framework.

Methods

Context

As part of their participation in the AR project, teachers received a small budget to purchase materials including computer equipment. The project also funded seven release days from teaching per teacher for each year (a total of 14 days). The teachers used the release time to find a focus area, develop research questions, review the literature, develop a plan for implementation, collect and analyze data, and to develop a multimedia presentation (artefact) about their learning. For most of the release days, one member of the research team was present to support the teachers. During the planning phases (3-4 release days), the teachers refined their research questions, read appropriate resources to help them understand how to set up the flipped classroom model, considered ethical issues, prepared information/consent letters for parents, developed data collection tools such as pre- and post-project student and parent surveys, and created timelines for implementation. A large portion of the planning was devoted to the selection of tools for students' use, which included videos designed specifically to help students learn, along with hands-on student-centred learning activities matched with curriculum outcomes. During implementation, teachers used release time to collect data and to organize and analyze the data during and after implementation. Finally, they used the remaining release time to represent their learning in the form of a multimedia presentation/artefact for other teachers.

The university research team that supported the teachers in the AR project included an education professor (first author) specialising in Science, Technology, Engineering and Mathematics (STEM) and in AR, along with a full-time professional learning facilitator, a doctoral research assistant and an AR project coordinator responsible for logistics. Overall, the role of the four-member university team was to collaborate with the four teachers to support, guide, facilitate, and scaffold their professional learning, troubleshoot problems, and answer questions. They observed classrooms and, in some cases, modeled teaching strategies. They also collected data from the teachers.

Data Collection

The analysis drew on four sources of data as follows:

1. Teachers' collaborative plans of action;
2. Teachers' ongoing, structured, written reflections;
3. Individual semi-structured interviews;
4. Post-project artefact created by teachers.

The observations are not included as a data source because they were designed to formatively support teachers in their activities, and not as a means of data collection. The plans of action (one per year) were completed by the teachers as a group collaboratively and in person during their release days. The plans were pre-structured with headings as follows: research questions, data collection, considerations (e.g., supports needed), ethical considerations, timeline, curriculum outcomes to be targeted, description of strategies and approaches, and professional resources (literature). The reflections were designed to be completed monthly and to guide teachers' ongoing thinking about their learning and practice. Each teacher completed three to six written reflections in each of the two AR cycles, except for Patrick who joined the project in cycle/year 2. Michael did not complete the monthly reflections because of personal time constraints, although he indicated that he reflected on his own in jot notes. With the exception of two prompts, the reflections were unstructured and invited teachers to descriptively recount important occurrences and events, and subsequently reflect on their meaning. The prompts invited them to identify challenges and feelings about the project. Each reflection varied from 300 to 600 words. Reflections were both descriptive (describing the planning and classroom implementation) and interpretive, where the teachers made sense of unfolding events and of how students were responding to the flipped classroom approach.

The interviews were semi-structured, meaning that in addition to a set list of questions, the interviewer could probe for clarification or depth and, where relevant, ask additional questions. The individual interviews were conducted at the teachers' schools, lasted approximately 60 minutes each, and were subsequently transcribed. Questions pertained to the following: personal background and characteristics; changes in practice and thinking; tools used; collaboration; data collection from students and; supports needed. The teachers' multimedia artefact was collaboratively conceptualized, designed, and created in the form of a video that could be shared with other teachers. The video explained teachers' interpretation of the flipped approach, how it was applied in the context of their classroom and how it affected their learning and the learning of their students.

Data Analysis

To analyse teachers' professional learning, we adapted a framework originally designed for workplace and organizational learning: Developmental Work Research (see Engeström, 2001). The adapted framework consists of four central questions as follows: "Who are the subjects of learning?; Why do they learn?; How do they learn?; What do they learn?" (Engeström, 2001, p. 133). The first question, *who are the subjects of learning*, refers to "the individual or subgroup whose position and point of view are chosen as the perspective of the analysis" (Engeström & Sannino, 2010). The question, *why do they learn* refers to the "object" of their activity or the purpose for learning. The question, *how do they learn* refers to the tools used for learning, and how these tools are used. Finally, *what do they learn* references the outcomes of their learning. Figure 1 summarizes this framework with hypothetical examples in the third column.

Who is learning? →	**Who are the subjects of learning? What are their characteristics?** →	*I am new to teaching.*
Why do they learn? →	**Why do they make the effort to learn? What is their object or purpose for learning?** →	*I want to be a better teacher.*
How do they learn? →	**What are they doing? What tools are they using to do it?** →	*I began by setting a timeline and schedule.*
What do they learn? →	**What are the outcomes of learning, positive or negative, intended or unintended?** →	*I became more confident using technology.*

Figure 1. Framework used to analyse the data.

We aggregated all data sources maintaining the participant reference in order to be able to subsequently identify to which teacher each quote belonged. We then identified units of analysis. These are "units that cohere because they deal with the same topic" (Miles & Huberman, 1994, p. 57). We grouped units into relevant categories corresponding to each of the four questions. For purposes of reporting, we selected those examples and quotes that best illustrated the response to the question.

Findings

Who Is Learning?

All four teachers were teaching grade six mathematics. Melissa and Jessica were in a rural school. Patrick and Michael were in suburban school. Melissa was in what she considered her first year of teaching apart from some substituting in previous years. Her Masters was in Physical Education. She had completed one math methods course. She added regarding her education, "It definitely didn't prepare me to teach math." At the start of the project, Melissa commented that she was "definitely nervous" because, as she explained, technology "was something I was learning, as a new teacher." She added:

> I was also learning the math curriculum. So it was a lot of new things. For example, from making a video, like the first video was like 'oh my god, how am I going to make my own video?' I was really stressed out about it and I was really anxious.

Jessica had been teaching for 10 years. She held a Bachelor of Education (Primary/Elementary) degree along with a Master of Education (Curriculum Studies) degree. Jessica did not enjoy teaching math. She was anxious yet excited about participating in the project. For her, participation represented somewhat of a risk in that, as she said, it is "challenging to step outside of your comfort zone." Jessica took one math course to enter the education program but she had had only one methods course during her undergraduate studies.

Michael had been teaching for 16 years. His undergraduate degree was in religious studies. He had already completed a Master's in leadership but was studying technology courses online through a Canadian university. He said, "I've always used technology.... Everything is pretty much self-taught. Technology is a major part of my classroom and the flipped classroom model allows for an easy transition." He remarked that he was like other teachers who always want to have things organized in class and "know what's next..." Michael described his biggest fear as the unknown. This was his first time participating in AR and he had always thought of a researcher as "someone who is at a university level."

Patrick had been teaching for seven years. He had completed an undergraduate math calculus course followed by the general math program in the education faculty. His background was in French as a second language and in history. He held a Master's degree in leadership. He was pleased to be part of the project, as he explained: "I never like to do the same thing twice. So that's why these kinds of opportunities to sort of stretch my teaching practice, I like to get involved with." He added that he liked diversifying. Patrick joined the project in year 2.

Why Do They Learn?

As part of planning, the teachers needed to choose a specific area of inquiry into their practice, such as an area of need. The teachers decided to inquire into the flipped approach in the mathematics classroom. Jessica explained that, initially, they wanted to explore, "How does the flipped mode affect achievement?" However, once they began reading about the approach, they decided to broaden the *why* of their learning. Jessica added, "No one in our group really knew a whole lot about it [the approach] going into it, but as we researched, we looked at how it affects not only achievement but motivation ... that really interested us, so we switched..." They articulated their research question as follows in their plan of action: "How would the use of a flipped math classroom help inform teaching practices to promote student motivation?" Their collaborative plan also referred to "moving towards a student-centred approach to learning as opposed to a teacher-centred, direct instruction approach" in order to motivate students. Melissa described her own reasons for participating in the project: "One of my goals – even it was on my growth plan in the beginning of the year – was to get more technology in my classroom." After one AR cycle, a new area of inquiry emerged that was not evident when the teachers first began. As Michael commented, they realized "if the parent is not involved in it, in some way, whether they're watching the videos or they're making sure that their child is watching the videos...the element of a flipped classroom is not really there." Patrick added, "parental involvement is

critical." In the year 2 plan of action, therefore, the four teachers added a sub-question: "What are parents' perceptions/attitudes of the flipped classroom?"

How Do They Learn?

Teachers learned using an AR cycle of inquiry whereby they iteratively and collaboratively planned, designed, implemented, observed, and reflected. Jessica explained how they planned: "October to February we met once a month and we discussed our plan, what the flipped classroom was going to look like, and the type of activities we were going to do and the preparation needed." They decided to focus on the unit of fractions in the first year and, in the second, "the math unit of ratio and percents," as Michael explained. Patrick described the process of planning as one that began with searching for literature and resources that could help them explore the flipped classroom. He added that they shared these resources with each other using Google Drive.

Next, they tried to find pre-existing videos to match the curriculum outcomes or create their own. Melissa explained, "...if they matched well, we used them, but then there were some videos where we were like 'We'll have to make our own video for that'.... if she (Jessica) made one video for one outcome, then I'd do the one for the next outcome." Patrick searched for "different resources online .... or even just fun, hands-on activities" that they could alter while Melissa continued to improve her methods of creating math videos. She used various tools including an app for iPad. She had to problem solve since "not all students have iPads." Michael added that they made videos "so that the parents have an understanding too." Teachers also gave presentations for parents and "provided them with information letters about the flipped classroom...." They completed a parent/guardian permission form and posted a slideshow online that Jessica created about the flipped classroom. They selected tools (e.g., Educreations) for the creation of the videos and adopted Edmodo as a classroom management system to support implementation with their students. They evaluated several technology tools that would allow their students to communicate their ideas and represent what they were learning. They selected a mind mapping tool and an animated video creation tool for this purpose.

Jessica described their constant communication with each other. Michael noted that they relied on each other, "always stayed in contact," shared documents in Google Docs, discussed their planning, and, after the fact, looked at results. Patrick commented on how they teleconferenced when they couldn't get together. As Patrick explained, they assigned themselves homework as a group with shared tasks. Michael noted that he was "the leader of technology [and] .... Jessica took the leadership role of kind of planning, keeping everything on one track." He added that they worked together as a set team. Throughout this entire process of implementation, the teachers reflected about what happened in the classroom. Michael reflected by keeping jot notes in a little book. Michael explained, "You're always reflecting on 'did this work today? Is there something I need to change for tomorrow?' Or 'what can I do to bring this child along a little bit easier [sic]?'" In addition, the university facilitator met with them. As Michael commented, the facilitator was someone they could go to, if they did struggle. Melissa added that she could email him with any questions and relied on him when she was uncertain how to proceed and he calmed her down and made her feel "more confident." He also visited her class to model activities.

The year-one plan of action outlined the implementation: "Videos will be viewed outside of class time … and students will come to class with questions or ready to apply new learning to activities tiered to meet their level of understanding ... work on problem solving activities in small groups..." Teachers and students used Edmodo for communication and interaction and for accessing content after class time. During implementation, as Patrick explained, they used to "walk around and observe and make notes of who's working well in the group, if they're on task, if they're struggling ... [and] steer them in the right direction." Teachers also collected data from students and parents using pre- and post-surveys in Google Docs. Patrick explained that, for ongoing assessment, they relied on homework organizers and "lots of different ...resource-based work, anecdotal notes, pictures, videos, student interviews...a rating scale and feedback form." He added that that they could see "what the kids really enjoyed or what they didn't enjoy, maybe to kind of tweak for next time around." Melissa added that they also took videos and pictures of students and anecdotal notes. They looked at students' work samples and, in Edmodo, the number of times the students would post or the types of things that they would post.

What Do They Learn?

Jessica felt that the project pushed her outside of her limits and increased her understanding of the curriculum. Her confidence grew so much that she felt she could never go back to the way she was before. She added, "I love teaching math now. That's my favourite subject to teach because of this project. It's totally changed my perspective." She realized that while she had to adapt to not always being "the centre of attention" she "enjoyed that when it came to teaching." The project also gave her an opportunity to become "more of a leader" as someone who presents at conferences and leads by "incorporating technology within the school." In terms of motivation, Jessica commented that her students "couldn't wait to do math." She added, "the whole atmosphere changed."

Melissa noted regarding the project that, "It was a really positive learning experience." She commented, "I was really pulling out the curriculum guide and making sure that I was covering each little outcome." As a result, she became more confident in using the curriculum guide. She added,

> And I feel more confident using the technology in the classroom .... [T]he first video was like 'oh my god! How am I going to make my own video?' But then I learned by using Smart Notebook, doing up the slides and then using ShowMe to record my voice.... [N]ow there'd be no trouble for me to go in and make my own video, for whatever subject...

Regarding motivation, Melissa observed that whereas students used to ask her if they had to do math, now "they were more excited to actually do math." The excitement was particularly evident with previously "really disruptive" students who became more focused.

Patrick observed that he and the other teachers had learned to be "more the facilitators of learning," leaving learners to their own devices. They were also "more in tune with the direct curriculum outcomes because [they] made a video for each of them." Before the professional learning project, he was "...under the impression that the video was the be-all, end-all of the project." Working closely with the curriculum, he realized that "just as meaningful, if not more

meaningful is the component of having the activities at the students' disposal and moving them through those activities that are going to enhance their learning in whatever concept or topic you're addressing." He referred to these as "meaningful, hands-on, engaging activities..." Designing videos and activities to match the outcomes made him realize "the need for more reflective practices... to mull over what went well, what didn't go well." In terms of negative, unintended outcomes, Patrick was disappointed with some parents' lack of involvement:

> That was the stumbling block and the learning curve for my parents; the ones that were involved were great, but there were ... parents in my room that had very little to do. Because of that, at times... there were quite a few lessons that went unwatched at home.... [A]nd that was a real point of frustration and challenge for me. Because you think of the time spent developing the video, and time spent communicating the importance of what we're doing to the parents, and e-mailing the parents and letting them know this is the third video that your son or daughter hasn't viewed – is there a reason? ... [W]e understand if there's a lack of Internet access at home. We accommodate that; we allow students to view them in the morning, or at some point when they first get into the building the next day, which is fine. But, for simply not doing it, that was frustrating to experience. Because then your whole lesson is sort of up in the air.

Patrick concluded regarding parental involvement:

> So, I think that's something that, moving forward, it's got to be better communicated that parents need to see the benefit of it ... it's nice to send home a letter, but who's to say that the letter's being read at all, other than just the permission slip being signed?

For Michael, the biggest impact was that he was reflecting a lot more, and "doing a lot of reading." He also learned about preparing content: "It really slowed you down as a teacher to say, these are the steps that you need to go through to learn this outcome." He learned about matching content to the audience: "...whether it's a video that we create or when we're in the classroom itself.... you've got to kind of get down to the student level..." He became more of a risk-taker and was more willing to allow students to make mistakes and learn from them rather than "guiding them constantly." He realized he did not need "to have that much control" in his classroom. His experience made him value new ways of knowing if, and what, students were learning: "I've learned that assessment is truly ongoing." He also learned to act as a leader with other teachers who didn't feel as confident, or as strong in technology.

Discussion

The purpose of this paper was to make sense of the professional learning of a group of four, grade six teachers of mathematics. The teachers were learning to use new tools in the form of AR along with a flipped classroom approach. We framed the analysis of the case of learning with its multiple sources of data by relying on a framework of four questions. We investigated who was learning and how, why, and what they learned. These questions focused coherent attention on subjects who are learning, their object (purposes) for learning, the tools that mediate their pursuit of the object, and the outcomes of that pursuit. Figure 2 summarises the responses to the four questions.

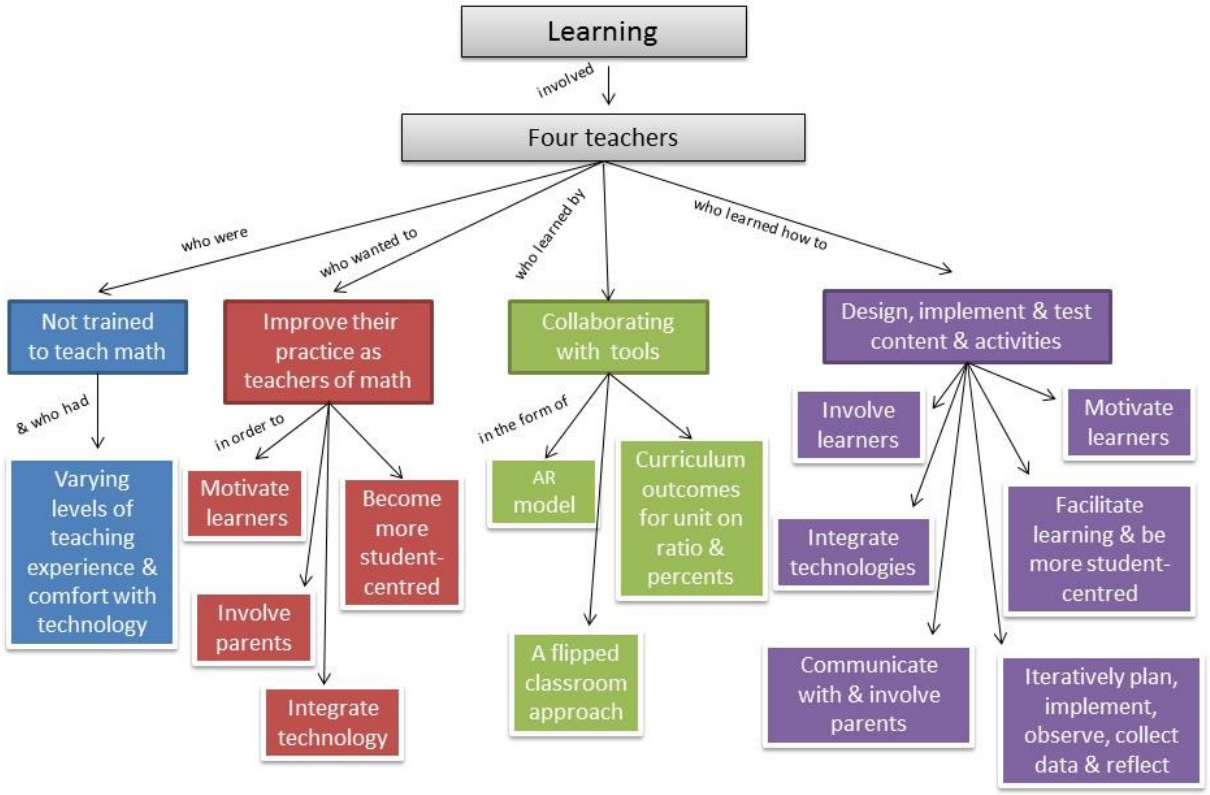

Figure 2. The who, why, how, and what of teachers' professional learning.

Who Is Learning?

The question of who is learning focused attention on the teachers' personal characteristics and backgrounds. The *who* made evident what they had in common as learners and how they differed. All were grade six teachers of mathematics without actual training or education in this area. Where they differed was in terms of their number of years' experience and their comfort with teaching. Their lack of expertise with teaching mathematics provided an underlying impetus to their learning. They needed to learn how to motivate students and be more learner-centred in teaching mathematics, something that they might normally have already learned if they had had an opportunity to be educated as math teachers. Expansion of their community beyond their own classroom to include other teachers, a university team, students, and even parents, helped them implement the new approach. These findings are consistent with those in the literature in terms of teachers' professional learning communities (e.g., Cochran-Smith & Lytle, 1999) that highlight the important role community can play in supporting teachers to learn new approaches and change their practice.

Why Do They Learn?

Regarding the *why* of their learning, the teachers were participating in the AR project in order to improve their practice. Initially, they wanted to motivate learners, make learning more student-centred, and learn to integrate technology into their practice In the second AR cycle, they wanted to involve parents in their children's learning. The question of why they were learning focused attention on a purpose for learning that is relatively new to their practice as teachers of mathematics. This purpose was to learn to foster more student and parental involvement in learning. Socially and culturally, there has not been such a direct role for parents in independently accessing curriculum content and activities. This purpose represented a transformation in teachers' practice. Engeström (2001) referred to this type of transformation as expansive. He explained: "an expansive transformation is accomplished when the object and motive of the activity are reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of the activity" (p. 137). The activity, in this case, was practice. Engeström explained that this form of learning occurs "where a person or a group begins to radically question the sense and meaning of the context and to construct a wider alternative context" (p. 139). In this case, teachers were moving from a conception of learning that is teacher-centred to one that was centred on students along with their parents.

How Do They Learn?

How they learned refers to how they pursued the purpose or object. This is an important question in this context given that the teachers were not trained to teach mathematics and had varying levels of expertise and comfort with technology. It is also an important question given that a teacher's purpose is a complex and comprehensive one. Unlike in a traditional context of professional development where the purpose may be to learn about a new approach, in this case teachers were learning to improve their practice. This complex purpose, combined with the characteristics of the teachers, creates challenges to achieving positive outcomes. Teachers' reliance on tools made it possible for them to achieve their purpose. These included AR and flipped classroom tools in addition to the curriculum outcomes for the mathematics units on fractions and on ratio and percents. The flipped approach scaffolded their learning about student-centredness. It provided strategies and other tools to shift their practices to engage in new forms of teaching activity. The AR facilitated their adoption of the flipped approach by providing tools such as the AR cycle, release time, strategies for teacher learning, an area of inquiry and feedback and support by a university team. Figure 3 depicts these AR and flipped classroom tools.

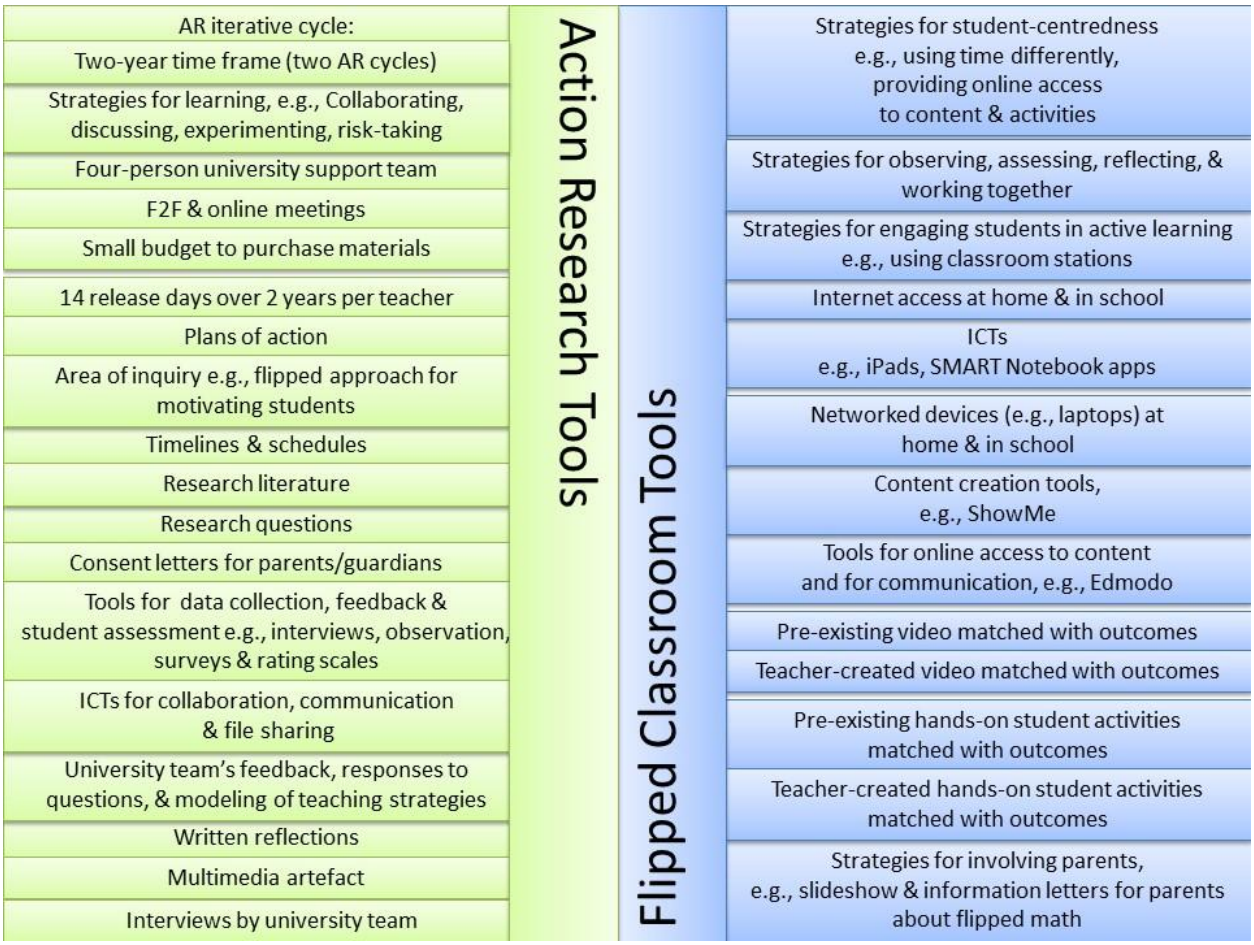

Figure 3. AR and flipped classroom tools.

Figure 3 shows the relationship between the AR tools and the flipped approach. As part of their participation in the AR project, the teachers needed to explore an area of inquiry. In this case, teachers decided to explore how to motivate students using the flipped approach. Examples of alternative areas of inquiry they might have explored include: improving problem solving through playing chess; using manipulatives for abstract thinking; or using mental math to improve calculation abilities. Just as the area of inquiry could have been different, so too could the timeframe; time is an important tool in learning and, in this case, the teachers benefitted from a two-year period and 14 release days. Figure 3 also shows the relationship between the flipped classroom tools and the curriculum outcomes. Teachers focused on fractions and on percents and ratios but could have chosen different units. What is important is that the approach was being used as a tool to further an effective focus on the curriculum.

The AR cycle also played an essential role in structuring and supporting the teachers' learning. It is possible that other cycles might serve a similar purpose. Examples of other cycles include Developmental Work Research (questioning, analysis, modeling, examining, implementing, reflecting and consolidating; Engeström, 1999), Learning by Design (inspire, ideate, prototype, evaluate, reflect, imagine and investigate; Kolodner et al., 2003), or Design-based Research (analysis and exploration; design and construction; evaluation and reflection;

McKenney & Reeves, 2015). An instructional design model such as ADDIE (analyse, design, develop, implement, and evaluate; Davis, 2013), could also scaffold teachers' activity as they implement a flipped approach. Whatever the cycle that is followed, findings of this study suggest that it should be followed collaboratively; in fact, collaboration is a tool in this case that allowed participating teachers to pool their resources, build on their strengths, and support each other in achievement of the purpose of their learning.

Figure 3 also highlights teachers in the role not merely as those who deliver learning, but as those who design it. The focus on instructional design in their learning is relevant particularly at this time given the technological tools and network capabilities that allow the creation and sharing of content and activities. Similarly, Mazur et al. (2015) found that teachers using the flipped approach in their AR project shifted their role "to a guide in learning" (p. 13) and "designers of learning" (p. 11).

What Do They Learn?

The *what* of teachers' learning turns attention to teachers' realisation of the object, or purpose, for learning. It also draws attention to unintended positive outcomes including the opportunity to develop leadership skills in relation to technology integration. Although it was not part of their original object, teachers learned a process of inquiry into their practice, that is, one that involved activities such as collaboratively planning, implementing, observing, testing, and reflecting. They learned how to match curriculum outcomes with online content and with activities. These are all skills that can be presumably transferred to other contexts. In general, the question of what they learned draws attention to the fact that teachers realized the purpose of their learning. For Patrick, however, there was an unintended negative outcome in that he struggled to involve parents. Unlike the others, Patrick only participated during the second year of the project. Had he participated in both years, he may have been able to focus more attention on parental involvement. It is also possible that his students and their parents were different in some way from those of the three other teachers.

Conclusions

The findings of this study have revealed that teachers with varying levels of subject-area expertise, comfort with technology, and experience with teaching were able to improve their practice by expanding their community and their tools. The AR tools and the flipped classroom tools scaffolded their learning so that they could improve their practice to make it more student-centred. We conducted a post-project analysis using a framework of four questions. These questions are important in a context of professional learning in which learning is not given from above, but rather it is driven by the learners themselves, and where the ultimate goal is to improve or even transform practice. Engeström (2001) referred to these contexts of learning as those in which, "we must learn new forms of activity which are not yet there. They are literally learned as they are being created" (p. 138-139). This framework of questions could be applied in other contexts of technology integration where teachers are experimenting with new tools and new forms of learning supported by these tools.

Limitations

This study was limited to a focus on teachers' professional learning with AR and the flipped approach. It was beyond the scope and purpose to include students' learning. Teachers reported that they were successful in motivating their students, but it was beyond the scope of this study to conduct pre- and post-tests to measure that motivation. The study did not involve taking measures of students' achievement. Therefore, although teachers reported that students were more motivated, we do not know if that motivation led to higher achievement. The study was also limited in that it was conducted under research conditions with supports that would not be available in most classrooms. It is not clear how feasible similar forms of professional learning with the flipped approach might be in contexts without, for example, the university support and the 14 release days. Furthermore, we do not know if teachers' learning was sustainable after the study, without the research supports. For example, will they continue to engage in inquiry and designing? Would they be able to transfer skills and knowledge learned in the first two cycles to focus on other areas of the mathematics curriculum? Sustainability and feasibility are important considerations in professional learning that involves designing new content and activities. Challenges identified by Mazur et al. (2015) in relation to the flipped approach included those related to the development of content. Similarly, Visnovska, Cobb, and Dean (2012) explained:

> The common assumption that groups of teachers are capable of designing coherent instructional sequences from provided materials with little if any ongoing support is a dangerous misinterpretation of both the potential of teacher collaboration and the fact that implementation is necessarily an act of design. (p. 339)

Implications

In terms of implications for research, it would be useful and relevant to investigate which of the tools are most likely to support adoption of new approaches, and which might be dispensable. Contextualized knowledge of this sort is important in order to determine the sustainability and scalability of professional learning initiatives involving AR and the flipped approach. For example, in a different context, and under different circumstances, could the release days be eliminated, minimized, or replaced? A similar question can be asked of the support and scaffolding provided by the four-member university team. The team's support could be potentially replaced by district coordinators and lead teachers. Reflections have been identified as highly effective tools for teachers' professional learning (see Schön, 1983, 1987), yet they may be more feasible in contexts such as this study where teachers are given release time.

A further implication for research as well as practice relates to the involvement of parents. The findings of this study made evident one important difference between K-12 versus post-secondary implementation of the flipped approach: that of parental involvement. The challenges faced by Patrick point to a need to better understand how K-12 teachers interested in implementing the flipped approach can effectively engage the involvement and cooperation of parents. K-12 teachers interested in implementing the approach may need to carefully plan for, and monitor, parental involvement.

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