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The effects of sustained classroom-embedded teacher professional learning on teacher efficacy and related student achievement

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ABSTRACT

This paper reports on the impact of a classroom-embedded professional learning (PL) program for mathematics teaching in two contrasting districts in Canada, and investigates the relationship between teacher efficacy and student achievement. Before the PL, District A had lower teacher efficacy and student achievement than District B, but after the PL, this situation was reversed. Qualitative analysis revealed that the two districts reported learning very different things from the PL opportunity. The complexities of context, prior learning experiences, goal setting, and persistence of participants all factored into what and how teachers learned.

1. Background

A large-scale professional learning program launched by the Ontario Ministry of Education in Canada aimed to strengthen school district capacity to enhance mathematics teaching and learning in Kindergarten to Grade 6 (ages 4–12). Key elements of the initiative included classroom-embedded mathematics professional learning, facilitation of school and district level professional learning networks, and peer coaching.

The professional learning model involved two facilitators working with groups of classroom teachers, and a vertical slice of support staff in 15 district school boards (12 English and 3 French language) in the province of Ontario, Canada. The professional learning model focused on: a) mathematics communication in the classroom; b) teaching and learning mathematics through problem solving using a 3-part lesson format (a lesson format that has three parts: an activation/minds-on segment; a development/middle segment that is problem based; and a consolidation/end segment); c) co-teaching of problem-solving lessons in classrooms; and d) collaborative analysis of student work samples. The facilitators participated in co-teaching with the participants and in classroom observations of planned lessons. The emphasis on quality mathematics teaching through standards-based mathematics teaching and learning strategies and content (see Principles and Standards for School Mathematics, National Council of Teachers of Mathematics (NCTM), 2000) were of key import. In alignment with Fenstermacher and Richardson (2005), the professional learning model emphasized "quality teaching":

> Quality teaching, we argue here, consists of both good and successful teaching.
> By good teaching we mean that the content taught accords with disciplinary standards of adequacy and completeness, and that the methods employed are age appropriate, morally defensible, and undertaken with the intention of enhancing the learner's competence with respect to the content studied…By successful teaching we mean that the learner actually acquires, to some reasonable and acceptable level of proficiency, what the teacher is engaged in teaching. (p. 191)

As part of this program, we examined the effects of the professional learning activity on teacher efficacy and student achievement. Subsequent analysis revealed interesting differences from district to district and led to a deeper investigation of the teaching and professional development practices of these districts and the related impacts of teacher efficacy and professional learning opportunities on student achievement. Essentially, we found that (i) inflated teacher efficacy based on invalid self-appraisal can be disabling. It impedes teachers' abilities to benefit from professional learning opportunities; (ii) teacher efficacy is a mediator, not a cause. That is, teacher efficacy does not directly create higher achievement. It operates indirectly by influencing teachers' goal setting and persistence. If other conditions are not

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present, teacher efficacy alone will have minimal impact; (iii) the key enabling condition in this study emerged from teachers' prior professional learning experience: it affected their goal setting (creating a felt need for change); it provided them with a conceptual foundation for recognizing how the professional learning content was of value to them (e.g., that they needed to meet curriculum expectations not textbook requirements); it equipped them with added capacity for collaborative learning.

2. Literature review

In this paper, we will explore the relationships between classroom-embedded teacher professional learning, teacher efficacy, and student achievement. Together, they offer a coherent framework for understanding the potential effects of *authentic teacher learning opportunities* (Webster-Wright, 2009).

2.1. Authentic teacher professional learning opportunities

In order to better understand the theoretical orientation and participant activity of the professional learning model in this study, we would like to distinguish professional learning (PL) from professional development (PD) because we see them as being distinct both in theory and in practice. We concur with Webster-Wright's (2009) review of over 200 studies on PD and PL that "professionals learn from experience and that learning is ongoing through active engagement in practice" (p. 723). However, the vast majority of educational PD programs have separated the learning opportunities from natural contexts and from practice. For example, PD sessions at the District level occur where teachers from various schools are brought together in a central location, are given a 'workshop' or are taught about a particular teaching or learning strategy. The underlying implication/assumption is that the teachers are deficient in some ways and require "topping up" on the latest pedagogical strategies that the teachers will then translate to their classrooms and implement with success. This traditional model extracts teaching professionals from their key professional learning environments (the school and classroom), and assumes that other experts know best what content and kinds of PD teachers need.

In contrast, we conceptualize teacher professional learning as embedded in the classroom context and constructed through experience and practice in sustained iterative cycles of goal setting/planning, practicing, and reflecting (see Kolb, 1984; Sankaran, Dick, Passfield, & Swepson, 2001). In other words, the whole social context of the classroom becomes the primary *and legitimate* site of teacher professional learning on an ongoing basis. We were interested in understanding PL opportunities that were clearly grounded in classroom practice using iterative cycles of teacher planning, practice, and reflection, and we wanted to know how these opportunities impacted both teacher efficacy and student achievement.

As part of this model of professional learning, we also consider the importance of teacher collaboration. Traditionally, teaching is understood to be a "uniquely isolated profession" (Hindin, Morocco, Mott, & Aguilar, 2007), yet teacher collaboration is identified by some researchers and educators (see Puchner & Taylor, 2006 for example) to be one of the most important features of school culture in order to foster teacher learning, satisfaction and effectiveness. However, collaboration that is driven by deep, personal and enduring interest and motivation (Wallace, 1999) is challenging to achieve. The level of trust and risk-taking required that moves teaching from isolated activity to the public sphere of professional learning communities (Fullan, 2007) should not be underestimated:

> … deprivatizing teaching will be much harder than anyone thought. Deprivatizing teaching changes culture and practice so that teachers observe other teachers, are observed by others, and participate in informed and telling debate on the quality and effectiveness of their instruction. I am not naive here. I realize that in punitive and otherwise misguided accountability regimes, teachers are ill-advised to open their classroom doors. But the research also reveals that even when conditions are more favorable, when implementation strategies are highly supportive, that many teachers subtly or in other ways play the privatization card (Fullan, Hill, & Crevola, 2006, pp. 2–8). Changing this deeply rooted norm of privacy is tough because such a change requires tremendous sophistication as well as some risk taking by teachers and other leaders. (p. 36)

2.2. Teacher efficacy

Teacher efficacy is a social cognitive theory founded by Albert Bandura (1993, 1997). Essentially, teacher efficacy is the teacher's self-assessment of his or her ability to support student learning. Teachers with high teacher efficacy believe that they can positively impact student achievement despite a possible range of perceived challenging circumstances (such as low socio-economic status of the students or a lack of resources). Teachers with low efficacy believe that they have a limited ability to influence student learning and achievement. A teacher with low efficacy believes that the locus of control is well beyond his or herself and there is little he or she can do to enhance student learning. Research in the area of teacher efficacy has produced an extensive body of literature (Bandura, 1986, 1997; Bruce & Ross, 2008; Gibson & Dembo, 1984; Goddard, Hoy, & Woolfolk Hoy, 2004; Ross, 1998; Tschannen-Moran & Woolfolk Hoy, 2001; Tschannen-Moran, Wolfolk Hoy, & Hoy, 1998) that demonstrates how teachers with high efficacy are more likely to persist to meet teaching goals when faced with obstacles; are more likely to experiment with effective yet challenging instructional strategies such as student-directed methods (Riggs & Enochs, 1990) and authentic assessments (Vitali, 1993); and are more likely to experiment and take risks in the classroom (Allinder, 1994). Teacher self-confidence to implement challenging strategies in the near future determines how effectively a teacher will actually employ these same strategies (Shachar & Shmuelevitz, 1997).

The four main sources of teacher efficacy information for teachers, according to efficacy research are: mastery experiences (direct teaching experiences that are challenging but highly successful); vicarious experiences (watching peers of similar ability levels teach challenging ideas with high success); physiological and emotional states (feelings of success and confidence); and social and verbal persuasion (receiving positive feedback from students, peers and superiors). Of these four sources of efficacy, mastery experiences are considered to have the most powerful influence on teacher efficacy (Bandura, 1997; Tschannen-Moran et al., 1998). Successes raise the expectation that a task can and will be mastered (Schunk, 1996; (Britner & Pajares, 2001) and failures lower expectations. Increasing confidence is the result of mastery experiences combined with classroom events that demonstrate the impact of the instructional strategies used. In other words, the teaching context matters: "[I]n making an efficacy judgment, a consideration of the teaching task and its context is required" (Tschannen-Moran, 1998, p. 228). Vicarious experience has been found to also be a powerful source of efficacy information (Bandura, 1997). In the case of vicarious experience, it is important to underline that the observing teachers are watching someone similar to themselves (and in a similar context) implementing a highly successful teaching moment.

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Teacher efficacy is strongly connected to teacher professional learning opportunities: When teachers participate in professional learning opportunities that provide them with mastery experiences (direct experiences embedded in the professional learning that lead to a sense of mastery), their personal competence level will rise (Pintrich & Schunk, 2002; Zambo & Zambo, 2008). Further, if a teacher is dissatisfied with the current level of student learning, student achievement and/or his or her own teaching "performance", there may be a self-directed desire for instructional change. In this situation, if the teacher also gains access to powerful strategies, through effective and context-embedded professional learning opportunities (Puchner & Taylor, 2006), the teacher then has the means to make the changes. Further, if the teacher is sufficiently motivated to sustain efforts and overcome obstacles (i.e., has high efficacy), the ability to implement these effective instructional strategies increases (Bruce & Ross, 2008).

2.3. The connection between student achievement and teacher efficacy

A key pocket of research has linked student achievement and teacher efficacy. Teacher efficacy is a reliable precursor to, and predictor of, student achievement (Muijs & Reynolds, 2001; Palardy & Rumberger, 2008; Ross, 1998; Ross, Bruce, & Hogaboam-Gray, 2006).

In order to illustrate the flow of this relationship, Fig. 1 summarizes the research findings.

People with high teacher efficacy are more likely to implement and persist with challenging yet effective strategies. For example, these teachers are willing to take the risk of having mathematics conversations move to areas where they are not fully confident of the content direction or the outcome (Smith, 1996). Teachers with high teacher efficacy also have high expectations for students because they believe students can achieve and they spend more time with low achievers than their low teacher efficacy peers (Ashton & Webb, 1986). When teacher efficacy is high, there is a greater belief that student ability can be improved (rather than seeing ability as a fixed commodity). These teachers create a classroom that encourages adoption of mastery orientations (approaching a school task for the purpose of learning something) over performance orientations (approaching a school task for the purpose of demonstrating superiority over others). Mastery orientations lead to deeper student understanding of mathematics concepts (see the review in Meece, Blumenfeld, & Hoyle, 1988). These teachers also have effective classroom management strategies that encourage students to take responsibility for their learning. All of these ongoing practices lead students to being better at self-regulation and to gaining deeper understanding of the mathematics concepts in focus. The students in classrooms where teachers have high teacher efficacy also have better study habits and develop habits of persistence during problem solving (Pintrich & De Groot, 1990). In essence, student persistence, deep conceptual understanding and self-regulation, all of which are developed in high efficacy classrooms, lead students to greater achievement.

Because of the intricate but indirect relationships between teacher efficacy, teacher collaboration, and student achievement, we determined to analyse the interactions between these constructs by examining and comparing the contexts and outcomes of two district school boards.

3. Method

The mixed-methods study used a convergence model of triangulation (Creswell & Plano-Clark, 2007) where both quantitative and qualitative data collection and analysis activities ran parallel and then converged results for interpretation. This was an effectiveness study, i.e., one that studied professional learning opportunities for typical teachers from a representative range of backgrounds working in 'regular' conditions, rather than a study that provides training to a specially selected cadre of teachers working in ideal circumstances. The sample consisted of French and English teams of teachers and students, nested within 46 schools in 15 school districts.

Quantitative data sources included pre and post teacher surveys and student achievement tests. The teacher surveys measured commitment to standards-based mathematics teaching (20 items from Ross, Hogaboam-Gray, McDougall, & Le Sage, 2003), three dimensions of teacher efficacy (12 items from Tschannen-Moran & Wolfolk Hoy, 2001), and self-perceived learning (15 items generated from the program theory of the in-service). All scales were reliable (alpha = .70+) on pre and post for the total sample of 88 teachers. Student achievement tests consisted of performance tasks involving six mathematical processes. Each test consisted of three open-ended questions and was administered within one 40-min period. Markers assessed each student's responses to the three questions as a whole, assigning a criterion-based score from 1 to 4 for each of six dimensions. The reliability of the total test, based on the complete student sample of 524 students, was alpha = .95–.96 for pre and post. For the student data, statistical analysis consisted of a series of within-subject analyses in which the repeated measures were the pre and post scores and the between-subjects factor was board (A or B).

Within the total sample of districts, there were five qualitative case study districts. In each case study site, classroom observations (in classrooms of participating teachers), participant interviews, and field notes from school and classroom-based professional learning sessions addressed questions of *how* the PD model was implemented and how it impacted professional learning communities, teacher practice, and student learning in classrooms. Individual case and cross-case analyses were conducted at length to

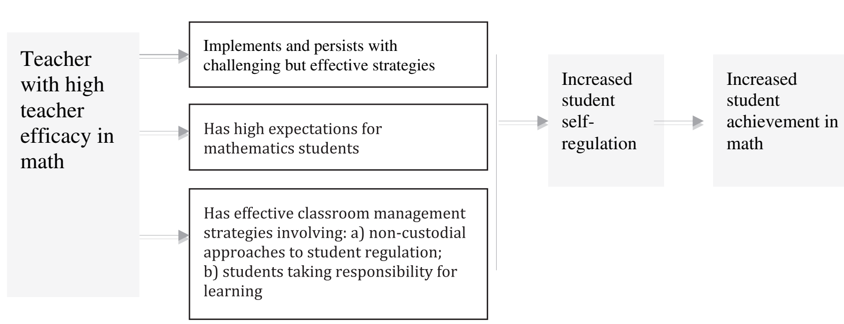

Fig. 1. The relationship between teacher efficacy and student achievement.

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look for both consistencies and unique characteristics of each case site: We used a multiple instrumental case study approach (Stake, 1995; Yin, 2009) and selected two sites with contrasting outcomes for this paper. Analysis consisted of coding the data from each case study independently (by separate researchers) based on agreed upon start codes (from key words and ideas in the texts). Codes were then reviewed and compared by the research team ensuring methodological triangulation (Creswell, 2008). Each case was then written up independently prior to the cross-case analysis.

3.1. Nature of the professional learning program

Participants met together in two-day sessions on six occasions throughout the school year. During these two-day sessions, participants gathered to set learning goals for students, co-plan a 3-part mathematics lesson (with an activation stage, a student problem solving/action stage, and a consolidation stage) and co-teach/observe the lesson in one classroom. Based on student responses to the task and analysis of student work samples, participants then revised the task and the lesson and co-taught/observed its implementation in the classroom a second time. The student work was analysed again to see how the lesson functioned and to determine specifically how students' responses reflected their depth and breadth of understanding of the mathematics. Teachers also co-planned and co-taught lessons between each of the two-day sessions in their home school (although this varied greatly from district to district). Emphasis on consolidation and boardwork (also known as Bansho) was emphasized by facilitators, as teachers consider this to be one of the most challenging aspects of 3-part mathematics lessons. Consultants, principals and superintendents all took part in the professional learning program, taking on teaching and observing roles in the group.

3.2. A closer examination of two district school boards

Once all data were analysed, researchers noticed interesting differences between district school boards even though the professional learning program was the same, and was even facilitated by the same mathematics education expert. The levels of teacher efficacy, student achievement, and levels of adoption of the overall program as well as specific pedagogical strategies emphasized during the professional learning program, varied. In this paper, we have selected two districts in order to illustrate how efficacy and achievement interacted with the professional learning program to produce different outcomes. Later in the paper, we will attempt to attribute these differences to a web of conditions.

3.2.1. District school board A

One of the salient features of this school board was the professional development program that the mathematics team (1 district level coordinator and 4 expert support teachers who worked directly with teachers in the district) had been implementing over six years in grades Kindergarten through 6 (in classrooms of 4 year olds to 12 year olds). Initially the board offered large-scale professional development, however, in the last four years the focus of attention had shifted to the development of small-scale professional learning groups that were tightly tied to classroom-based teaching and learning activities. The district level mathematics team made this shift because they observed no changes in instructional practices nor student achievement when they applied the large-scale professional development model. Upon reading current research, the team decided that classroom-embedded and teacher-directed professional learning opportunities that focused on long-term small group collaboration would be more beneficial. They began with less than 15 teachers in year one of their small group approach. In year two, the group expanded and added the classroom observations and co-teaching elements. By the time of this study, there were three groups of 40 teachers (120 total) involved in the teacher-directed professional learning activities (Coordinator, interview).

The intent of these small groups (professional learning communities) was to develop knowledge of mathematics-for-teaching among interested teachers through collaborative practices that linked practice with theory. The stated goals of this learning program were to:

- Build teachers' expertise in setting classroom conditions in which students can move from their informal mathematics understandings to generalizations and formal mathematical representations.
- Have teachers experience mathematical problem solving [and high-yield instructional strategies] – considering the ideas of others; understanding and analyzing solutions; comparing and contrasting solutions; and discussing, generalizing, and communicating – as a model of what effective mathematics instruction entails.

(Mathematics coordinator, focus group interview)

The coordinator provided opportunities for the teachers to meet in small groups with expert support teachers to collaboratively design and implement mathematics lessons that emphasized student problem solving and math talk, with specific attention to deeply understanding the mathematics in each problem.

Teacher participants in the Ministry of Education initiated professional learning program were almost all members of this group of 120 teachers who had been learning together over several years. There were three school teams in this district that included administrators, lead teachers and participating teachers. Their levels of experience ranged from 5 years to 25 years as educators. Although there were teachers in each school team who were relatively traditional in their approach to teaching, there were also participants in each school who were implementing inquiry-based mathematics programs due to their prior experiences in the district level PL activities. One of the three schools was urban, with a diverse population of students, while the other two schools were rural with little diversity.

3.2.2. District school board B

District B was of a similar size to District A. It was situated in a small city in Ontario, and served approximately 22,000 elementary and secondary students per year. Several schools from this district and its coterminous district were chosen for the project, and teachers from grades 2 and 2/3 (ages 7–9), as well as expert support teachers from these schools, were encouraged to participate. Approximately 10% of students in the district were identified as special needs, and less than 10 students (total) were classified as English Language Learners.

Teachers and administrators in this district commented several times throughout the sessions that they had focused large-scale, traditional, professional development mainly on literacy in the recent past, and they lacked experience with mathematics PD. For example, in an interview, one of the administrators reflected on the impact of the mathematics PL experience: "[the PD] really showed me that I didn't know a lot about math. And, that's terrible to say. But, there's been so much PD around literacy" (Administrator, individual interview). Thus, many of the strategies of teaching through problem solving and analyzing student mathematical thinking were unfamiliar to the majority of participants. Another administrator commented, "the Bansho, that's been something huge in our school. We've never done anything like that"

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(Administrator, individual interview). Most of the participants reported that this was their first intensive mathematics professional learning experience. Participants from this school board also emphasized that their curriculum consultants/coordinators were generalists – consulting on both mathematics and literacy – and were not "math specialists". Their time to consult on mathematics teaching was limited and they were spread thinly across various sites.

The three schools involved in the Ministry project each had several Gr. 2 or 2/3 teachers (students of ages 7–9). The lead school was located in a subdivision of single-family homes, with a park nearby. Researchers were informed that teachers were not used to having administrators or other teachers enter their classroom to observe or to collaborate, and that co-teaching was an entirely unfamiliar process. The teachers reported that they associated principal and superintendent visits/observations with evaluation and thus were viewed as stressful occasions.

> "I could have twenty strangers watching me and I would care less. These are my principal, my superintendent, these are all the people that are, very important people above me, my bosses, watching me, do something I'm really not sure how it's supposed to go, but I'm going to give it a try, and wing it." (Teacher, focus group interview)

4. Anticipated outcomes

In examining the pre data for District school boards A and B, we noticed some unusual results. To begin, the teachers in District A had reasonably high teacher efficacy and in District B had even higher teacher efficacy (when rating themselves on a 6 point scale, the means were well above the mid-point of the scale – see Table 1). On all pretest teacher measures (support for standards-based teaching and three dimensions of mathematics teacher efficacy), teachers in District B rated themselves higher than the teachers in District A. This was surprising because District A had carefully planned and implemented a four-year classroom-grounded professional learning program prior to the current Ministry initiative and therefore, researchers assumed that teacher efficacy would be higher compared to a district where very limited professional learning in mathematics had taken place.

One theory we have considered is the possibility that because of the sustained, reflective, and questioning nature of the teacher professional learning community in District A, the teachers had a more accurate estimation of what was possible, and the teachers were therefore knowledgeably self-assessing their abilities to impact student learning. Response shift bias, i.e., evidence that the respondent's underlying metric has been recalibrated from pre to post, has been demonstrated in several fields (Cantrell, 2003; Sprangers & Hoogstraten, 1991). Thus, an explanation might be that District A teachers had a more accurate understanding of the challenges and effort required of mathematics teachers regarding listening to students, eliciting students' mathematical reasoning, and focusing on deep understanding of core mathematics concepts. In addition, the relatively high achievement of District B students might have supported their teachers' relatively high teacher efficacy.

Our second assumption was that student achievement would follow teacher efficacy because the body of research to date illustrates a close relationship between teacher efficacy and student achievement. That is, because of the high teacher efficacy results, we expected District B would also have higher student achievement levels than District A on the pretest. This proved to be true: District B students scored higher than District A students on five of the six pretest achievement variables. On four of these five, the differences were statistically significant [shown below in the results section]. On the sixth variable there was a slight advantage for District A students over District B; this difference was not statistically significant. Therefore, the student achievement data matched the teacher efficacy data in the pre-surveys.

These results led us to ask questions about what the student posttest and teacher survey results would reveal. What results should we anticipate at the end of the first year of this professional learning program? Would teacher efficacy increase, and for whom? Would student achievement increase and for whom? Based on the pre-survey results for teacher efficacy and research in this field which illustrates how high quality professional learning consistently increases teacher efficacy, we anticipated that both districts would increase in their teacher efficacy at approximately the same rates.

We developed two competing hypotheses related to student achievement. That:

1. Both Districts would have increased student achievement scores because the professional learning program was the same: District B would continue to have higher student achievement scores than District A on the posttests because the students began at a higher level of achievement at the onset of the professional learning program and the teachers in District B began with higher teacher efficacy scores.
2. District A would have higher change scores for student achievement than District B (i.e., the positive difference between post and pre would be larger for District A than District B) because the in-service was likely to have a greater effect on teacher practice for those with sustained classroom-based prior learning experiences. It occurred to us that the teacher efficacy scores in District A were ready to climb with continued high quality professional learning opportunities.

In a simple graphic representation, hypotheses 1 and 2 would look something like Figs. 2 and 3.

In addition to the quantitative analysis of teacher efficacy and student achievement, we also conducted a qualitative analysis of teacher learning in the PL program. Case studies allowed us to gather substantial data on goals, attitudes, participation levels, types of activity, and key learnings of the district participants. This analysis relied on interviews with the teachers and other participants, video documentation, and field notes of the formal and informal professional learning sessions.

5. Results

5.1. Teacher efficacy results

Table 1 shows the means and standard deviations for both boards on the pre and post teacher surveys. Because the number of cases is so small, no tests of statistical significance were performed. We represent differences using effect sizes (Cohen's d). The top

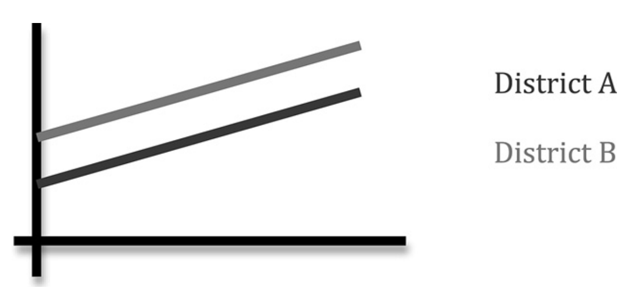

Fig. 2. Graphic representation of hypothesis 1: student achievement change over time.

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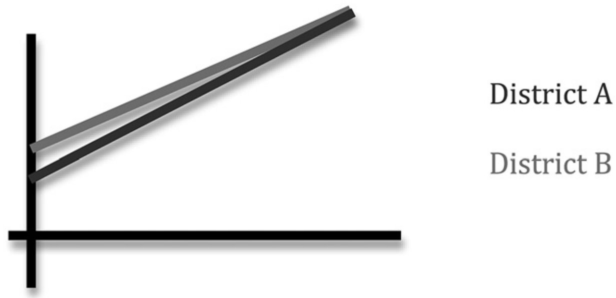

Fig. 3. Graphic representation of hypothesis 2: student achievement change over time.

panel of Table 1 shows that District B scored higher on all pretests and the effect sizes were large.

The bottom panel of Table 1 shows that District A teachers gained more from the in-service than District B teachers. The large pretest advantage on the teacher measures disappeared on three of the variables, reversing direction on two of them so that District A teachers scored higher than District B teachers on commitment to standards-based teaching and on teacher efficacy for managing student behaviour in the mathematics class. On the fourth measure, teacher efficacy for using a range of instructional practices, the differences had shrunk from more than two standard deviations to one-sixth SD. In addition, District A teachers scored higher than District B teachers on the post-only scale of self-perceived learning (i.e., how much teachers thought they had learned in the in-service). We anticipated that teacher efficacy would rise at a steady rate for both Districts engaged in the PL program, however the teacher efficacy scores at District A rose more dramatically, and in 3 of the 5 categories, surpassed the teacher efficacy scores of those in District B.

5.2. Student achievement results

Table 2 displays the results for student achievement. There are six scores representing the six dimensions of student achievement. The top panel of the table shows that on the pretests, District B students scored higher than District A students on all but one of the achievement measures. The differences ranged from small to medium size (ES = −0.17 to −0.78). Comparing the top and bottom panels of the table shows that District A students gained more from pre to post than District B students on all but one of the achievement measures. The exception in both pre and post District comparisons was for the mathematical process of making connections. The achievement differences between the boards changed direction: on all posttests, District A students outperformed District B students. The District differences in changes from pre to post were statistically significant on two of the measures: content [$F(1,158) = 4.39$, $p = .002$] and communication [$F(1,158) = 5.07$, $p < .001$].

The six mathematical process scores were combined in to a single score for pretest and a single score for posttest (each score was the mean of the six process scores). Fig. 4 plots the results: District A students improved from pre to post while student performance was virtually unchanged from pre to post for District B students. The board differences were statistically significant [$F(1,165) = 11.60$, $p = .01$].

5.3. Qualitative findings

We now turn from the quantitative analysis of teacher efficacy and student learning, to a qualitative analysis of teacher learning in the PL sessions. Participants came to the PL experience with a wide range of prior experiences. These prior experiences influenced the speed and confidence with which participants came forward to take on leadership roles in the project, as well as affecting the level of learning that occurred.

Two of the most clearly beneficial aspects of the PL activity were the context-embedded experiences during the research lessons that occurred in classrooms, and the conversations that occurred between colleagues as they shared examples of student work. The professional learning program provided an opportunity for educators to collaborate with one another and share positive teaching practices and strategies. Over the course of the project, participants gained greater confidence in their abilities to support student learning and in their mathematics pedagogical content knowledge. This manifested itself in participants' increasing willingness to contribute to discussions about lessons and student work, volunteer to teach and co-teach, and volunteer to chair meetings. Nonetheless, there were different levels of acceptance and resistance to the learning opportunity.

In District A, teachers began reluctantly but then embraced this new learning opportunity as a means to further extend their inquiries into teaching and learning mathematics. In interviews, teachers reported 3 key areas that supported their professional learning:

1. Having the opportunity to consolidate professional learning from the previous three years of activity with the support of external knowledgeable mathematics facilitators in the Ministry PL program.

> I have worked with [the district PL group] for three years, so it [problem solving] has been in my classroom. But there were so many things I picked up to improve, and I realize that I was stagnant. … One of the things I learned was … the realization

Table 1
Means, standard deviations and effect sizes of teacher variables by board and test occasion.

Teacher variables	Board A ($N = 5$)		Board B ($N = 3$)		Effect size
	Means	SDs	Means	SDs	
Pretest scores					
Commitment to standards-based teaching	4.67	.44	5.22	.46	−1.22
Teacher efficacy: ability to engage students in mathematics tasks	4.00	.90	4.75	.43	−1.06
Teacher efficacy: ability to use a range of instructional mathematics practices	3.75	.56	4.75	.25	−2.31
Teacher efficacy: ability to manage student behaviour in the mathematics classroom	4.25	.64	4.67	.38	−0.80
Posttest scores					
Commitment to standards-based teaching	5.00	.61	4.88	.37	0.24
Teacher efficacy: ability to engage students in mathematics tasks	4.25	.81	4.25	.50	0
Teacher efficacy: ability to use a range of instructional mathematics practices	4.40	.70	4.50	.43	−0.17
Teacher efficacy: ability to manage student behaviour in the mathematics classroom	4.70	.45	4.42	.52	0.58
Self-perceived learning through the PL program	5.07	.57	4.81	.51	0.48

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Table 2
Means and standard deviations of student achievement variables for Districts A and B.

Student achievement	Board A ($N = 90$)		Board B ($N = 78$)		Effect size
	Mean	SD	Mean	SD	
Pretest					
Content	2.01	.74	2.58	.73	−0.78
Problem solving	1.90	.65	2.40	.67	−0.76
Reasoning	1.73	.61	2.09	.72	−0.54
Representation	1.80	.64	2.23	.60	−0.69
Communication	1.71	.62	1.82	.66	−0.17
Connections	1.78	.70	1.68	.66	0.15
Posttest					
Content	2.43	.91	2.27	.68	0.20
Problem solving	2.26	.86	2.24	.69	0.03
Reasoning	2.11	.79	2.10	.66	0.01
Representation	2.24	.84	2.23	.66	0.01
Communication	2.13	.78	1.91	.67	0.30
Connections	2.04	.75	2.03	.76	0.01

that when students articulate their problem solving strategies, that wasn't [the same as] their [mathematics] learning. (Teacher, focus group interview)

2. Having the opportunity to observe one another teaching enabled teachers' vicarious experiences (seeing a colleague similar to themselves teaching a lesson successfully), which increased teacher efficacy. For example, in one of the most engaged schools, a teacher described the benefits of professional learning that was directly embedded in the classroom:

> I think we were the people who benefitted the most, because it was our lessons and coming into our classrooms and working with our students, and having that experience…and I think although sometimes it was a bit big and crazy, I think we learned more because we were in the trenches ultimately. (Teacher, focus group interview)

3. Having the opportunity to closely examine student work was considered the third key learning strategy. Every teacher interviewed commented on their interest in analyzing student work with the support of a facilitator because it gave teachers time to focus on the mathematical content of the tasks:

> For me, the most important part was where we looked at the math in the samples. When the discussion was led by [the facilitator] and she said 'let's dig deep into the math, what's going on with the math' and she pointed out different stages in development – wow – for me that was huge. And then thinking about how to use that for instructional decisions, based on where the kids are at. What decisions to make to support their math understanding: That was always the best part. (Teacher, focus group interview)

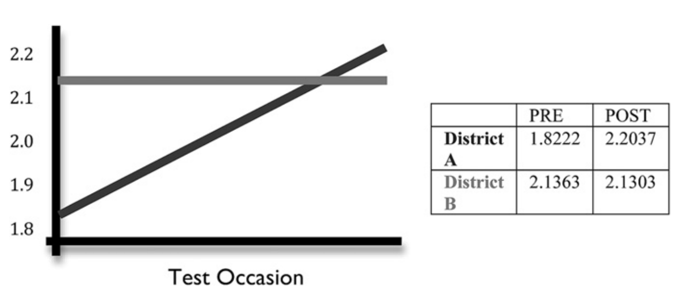

Fig. 4. Pre and post student achievement results for Districts A and B.

In order to find a specific measure for teacher ownership of the professional learning, case study researchers of District A calculated the number of times teachers contributed during PL sessions compared to principals, facilitators, and superintendents. Results showed clearly that teachers increased their contributions from the first formal session to the last.

Table 3 illustrates the shifts in whole group discussion contributions from session 1 to session 6 in terms of the overall percentage of contributions by participant role (1 ministry facilitator, 24 teachers, 7 administrators, 4 consultants/coordinators, 3 Ministry personnel). Contributions (based on the unit of an utterance) from the facilitator decreased from 58% to 41% of the conversation, while the teacher contributions dramatically rose from 9% to 36%.

In District B, the nature of teacher learning reported by teachers in the study focused on three other aspects of the professional learning: (1) the three-part lesson structure, (2) attending to students, and (3) the role of the textbook and curriculum expectations.

1. *Three-part lessons*

Field notes and interviews suggest that prior to the PL program, teachers may have been accustomed to more traditional, direct-instruction teaching approaches. This was evidenced by (a) teacher articulation of a need to instruct students about procedures and concepts at the beginning of a unit before engaging in the inquiry process and (b) teacher articulation of the difficulty they experienced letting students "struggle" with problems. These teachers felt the need to intervene when students were having difficulty.

When the PL program began, most of the teachers seemed unfamiliar with the three-part lesson structure of activation, development, and consolidation. Over the course of the six two-day sessions, the teachers learned and discussed the format of the three-part lesson. The professional learning sessions focused at various times on the different components of the lesson: choosing tasks for the Activation, Development, and Consolidation, anticipating student responses, listening to student thinking, deciding which pieces of student work to discuss during board-work, and so on.

One of the expert support teachers reported in an interview that in response to the PL, the teachers had changed the way they designed mathematics lessons. The consultant stated, "I think teachers are learning how to listen to students and talk differently, listen more, talk less. … and the talking with students during problem solving has shifted from telling, to tell me about your thinking" (Expert support teacher, focus group interview). The emphasis on lesson structure was important to the teachers in District B, because this was a new structure that required time to understand and implement.

Table 3
Percentage of contributions during whole group discussions by role in District A.

Role	# of Participants in the role	Session 1 (%)	Session 6 (%)
Facilitator	1	58	41
Teachers	24	9	36
Consultants	4	18	11
Administrators	7	11	8
Student achievement officers	3	4	4

Please note that the number of participants in each role makes it difficult to assess exact levels of contribution by role but our intention in including this data was to simply illustrate the shifts in contributions by participants over time.

2. *Attending to students*

On a related note, researchers observed a shift in the ways that teachers talked about students in the PL sessions. At the beginning of the PL effort, the facilitator stated that one of the goals of the PL program was for participants to learn to describe student mathematical thinking in more detail and specificity. Over the six two-day sessions, the facilitator pushed participants to listen to the details of student thinking, rather than describe overarching states of being such as on-task/off-task behaviours, levels of motivation, and student interest. Field notes of discussions in the PL sessions demonstrate an increase in the specificity of teachers' comments about students over time. Specifically, in later sessions teachers became more explicit and focused when discussing children's mathematical thinking. In an interview, one of the expert support teachers commented on this shift, saying

> And also when observing students and listening to students work in groups it's moved beyond how they work together, how they cooperate or don't cooperate, how they fight over…we're moving beyond those kind of observations which have a time and a place, but when we're looking in a math context, it's not the time or place. So, we're really starting to look at the math in more detail. (Expert support teacher, interview)

This consultant/coordinator asserted that teachers learned to talk more about mathematics and to tease apart the different ways that students tackled mathematical problems. This shift spread beyond the PL context itself and was observed by the consultant in outside conversations with the teachers.

Some teachers also reported their surprise at what students could do without explicit instruction. Teaching through problem solving seemed to have afforded more opportunities for students to engage meaningfully with mathematics, thus providing teachers more to observe and talk about with respect to student thinking. However, one administrator told us that she observed variability in how much the teachers took up the three-part lesson format and problem-based learning outside of the formal whole group PL sessions. This administrator reported that at least one teacher remained fairly traditional, whereas other teachers had more wholeheartedly incorporated new strategies.

3. *Role of textbook and curriculum expectations*

In Canada, the curriculum expectations are prepared and distributed by the Ministry of Education and describe what students are expected to learn from year to year. Textbooks in Canada are print-based support documents generated by independent publishers that provide activities based on the curriculum expectations. The teachers of District B reported a shift in the ways they used the textbook. They reported surprise that the textbooks did not match the curriculum expectations exactly. In the PL sessions, the facilitators had emphasized the importance of beginning with the curriculum expectations and Ministry of Education guidelines. This was a novel approach to the teachers, who said that they typically taught with the textbook only (or their own activities, based on the textbook) and rarely considered the curriculum expectations. While this was not a major point of the PL sessions (in comparison to the discussions of student thinking and of teaching through problem solving), the teachers, administrators and consultants all commented on the value of this approach. For example, one expert support teacher told us,

> One teacher that I worked with would say to you wholeheartedly, "the biggest thing I learned is to start with the curriculum, not the textbook." [The teacher] left out complete sections of transformational geometry in grade two. "I looked at my curriculum, I don't have to teach that, so I'm not going to! " That's big, that's huge. (Expert support teacher, interview)

5.4. *Change in participant contributions over time*

Field notes revealed that in earlier sessions the session facilitator spoke the most during large group discussions and teachers tended to speak only when directly questioned. The session facilitator spoke at length about the CIL-M model as well as the three-part lesson and this was likely because for many of the participants in this district, these were new or relatively new teaching concepts. Teachers' participation was limited to small group discussions. Coordinators and administrators, however, participated in large group discussion to a relatively greater extent. Over time, there was a shift in the type of contribution made by all participants. Specifically, in May and June sessions, teachers, administrators, and coordinators spoke far more during large group discussions relative to January and February sessions. In these later sessions, for example, teachers significantly contributed to analyses of student work and consultants led public-lesson debrief discussions. A change in role allocation could also be seen in later sessions as coordinators became session facilitators and these coordinators contributed significantly to discussions during debrief sessions.

5.5. *Studying the professional learning context to make sense of the results*

The findings we report here are quite striking. The district that initially had higher teacher efficacy and higher student achievement was surpassed on both teacher and student measures by the other district. To interpret these quantitative findings, we drew on field note and interview data to explore what teachers at the two districts learned from the PL sessions, and we observed that the two sets of teachers had learned different things from ostensibly the same PL experience. District A, with a large complement of teachers who were experienced with reform-based mathematics instruction, was able to take advantage of the PL sessions to understand their mathematics teaching practices, and their students' mathematical thinking, more deeply. District B, with much less prior experience with mathematics professional development, seemed to be just beginning the learning process and their focus was on more superficial aspects of teaching through problem solving.

Explaining why these differences came about requires us to return once again to the data, to understand more about the context of the schools and districts, and the actual activities of the PL sessions. In this section, we draw on the qualitative data to provide multiple possible explanations.

One major explanatory factor is the teachers' previous experiences with mathematics professional learning. District A was in their fifth year of collaborative PL on mathematics teaching, while District B was just beginning this work. Far from demonstrating a ceiling effect in terms of teacher learning and its impact on students, the results suggest that even after 5 years studying mathematics pedagogy, the District A teachers benefitted greatly from the opportunity to collaboratively explore teaching through problem solving and attend closely to student work. The coordinators and expert support teachers in the district were also able to strongly support the teachers in shifting their teaching practices due to the ongoing relationship developed through their prior work together. The majority of teachers in this group had already read research and discussed it together, analysed the mathematics curriculum in detail, co-planned and co-taught lessons, and analysed student work in mathematics together. This prior collaborative activity fit seamlessly with the

Ministry project and enabled the group to take risks together and expand their professional learning further (Coordinator, interview).

It may be that if the teachers in District B were to continue for another year of the program, their learning gains might increase substantially because of the sustained approach to professional learning. Part of the lack of professional learning in mathematics may have led District B participants to focus on surface features of the PL program more readily, such as the use of the grade level expectations as the primary impetus for lesson development. District A participants were able to move quickly beyond surface or basic features of the PL program to engage more deeply in the co-teaching and student learning aspects using problem-based tasks.

The level of prior experience with mathematics professional learning was associated with varied rates of risk-taking by participants. For example, when one of the District B teachers was contemplating what topic to choose for her next problem-solving lesson, she opted to teach a lesson on a topic that was familiar to her students, rather than setting a problem based on a brand-new topic. During a meeting of administrators involved with the project, one of the expert support teachers from District B described the problem:

> Because the teachers knew that they were going to be involved in the PD this week, however, they did not want to begin a new topic. They felt the need to have time to prepare their students for the public lesson. The teachers expressed concern with introducing the students to a new topic when the PD sessions were taking place. (Field notes, PL session).

In discussions when the teachers were planning their co-teaching lessons, they described feeling nervous about trying a higher risk strategy as part of the PL activities: With approximately 20 visitors in the classroom observing the lesson, this teacher opted for a safer lesson involving concepts she felt her students already knew. Nonetheless, teachers in this group reported that they learned a lot about student thinking and were surprised at what their students were able to do and understand during the problem-based lesson. “And, [I] realize that students can teach one another. They learn from one another…they know a lot more than, you sometimes realize” (Teacher, focus group interview).

In contrast, in District A, participants were eager to try out risky problem-based lessons, building on prior experiences. This included attempting tasks with students that were highly challenging. For example, in describing a classroom lesson she implemented between sessions, one teacher exclaimed:

> The other day I was co-teaching an algebra problem. And we were all thinking, ‘wow, pretty complex problem’. And I was moderating the discussion. And I did it! I pulled out the math! I had a purple marker, and I was circling things, and writing down things, and making connections and I’m like, ‘ok, this is the equation using variables…and this is the equation using constants and variables’ and I was like, ‘YAY! I actually did it!’ (Teacher, focus group interview)

Further, the tone of the PL sessions was quite different from one district to the other. In end-of-year interviews, the District A teachers were overwhelmingly positive about their experience, while the District B teachers were primarily ambiguous in their assessments. Field note analysis revealed that in both districts, the PL sessions were initially rocky, with tensions around the choice of teachers participating, the choice of times and days, and the amount of work teachers felt they had to put into the project. However, over time, the teachers in District A came to participate willingly in the sessions. In District B the teachers exhibited resistance throughout the sessions, reluctance to participate, but when prompted, acknowledged the valuable learning that had occurred. Given this climate, the teachers in District A were able to accomplish more in the PL sessions and beyond the PL sessions.

Perhaps the most striking difference between the two districts involved the degree of between-session implementation of a problem-solving approach in participants’ mathematics classes. Because District A was already engaged in learning to teach mathematics through problem solving, their teachers tended to implement such lessons routinely and found the additional professional learning to be a catalyst for further implementation.

> But there were so many things I picked up to improve… The whole process gave me a kick in the rear! Don’t rest on what you know! (Teacher, focus group interview)

For District B, this method of teaching was new. In interviews, District B teachers reported only occasionally implementing the newly learned teaching techniques between the formal PL sessions. One consultant reported in an interview that “they only do [teaching through problem solving] once a month.” In District A, not only did teachers co-plan and co-teach lessons in their respective schools but they also independently arranged observations in one another’s classrooms. These lessons were observed by researchers during the time of the project and formed the basis of field notes on more than 5 occasions. On the other hand, in District B, no teacher was observed co-planning, co-teaching, or implementing a three-part lesson other than during the formalized professional learning days that they were required to participate in between PL sessions.

6. Discussion

In this paper, we began with research and theories of teacher efficacy and its effect on student achievement, and posed two competing theories about how a PL experience might influence efficacy and student achievement. We found some striking results that necessitated a closer look at the qualitative data to further understand the outcomes.

Specifically, we contrasted two school districts, one with a history of mathematics professional learning, and one without. The teachers in the school with the least knowledge of effective mathematics teaching practices actually had higher efficacy and higher student achievement scores than the District that had engaged in a comprehensive mathematics professional learning program. After a sustained and intense year-long professional learning program, the situation was reversed. The mathematics teachers with greater prior professional learning experiences increased their efficacy more than those of the other District, and their students learned more. We partially explained this finding by looking at what the teachers had learned and how they had participated in the PL sessions. The context of the PL was necessary to explain this counter-intuitive finding.

There is consistent evidence in the literature that improvements in teacher efficacy and professional actions are reciprocal. In this study, teachers in board A appeared to be on an upward spiral: (i) they made changes in their instructional practice in response to the professional learning opportunities; (ii) these changes resulted in student learning improvements; (iii) the increased focus on student thinking (a theme of the PL) enabled participants to see that their actions had beneficial outcomes for students; (iv) these conditions of enactive mastery experiences contributed to higher teacher efficacy; and, (v) increases in teacher efficacy energized greater classroom effort, re-launching steps (i) through (v).

But why did District B teachers not experience the same upward spiral? Based on our findings, we suspect that the District B teachers had high teacher efficacy beliefs that were based on untested self-appraisals. Because they had not had the sustained prior PL experience of District A teachers, they did not recognize that their professional practice was at a fairly low level compared to the expectations embedded in reform mathematics education. District A teachers had a felt need; i.e., they recognized from prior PL that their performance was not at the level they wanted it to be. They seized upon the PL as an opportunity to improve their practice. In contrast District B teachers did not see a need to change and saw the PL as taking them in a different direction than where they were. For example, the PL focused on curriculum expectations rather than textbook coverage. Instructional change was minimal for District B teachers because they did not put into practice, between sessions, the content and pedagogy of the PL, presumably because they did not see that the new practices were going to help them very much. Because there was no instructional change, there was no achievement change.

In addition, prior experience created a capacity for collaborative learning that enabled District A teachers to benefit in two ways: First, it enabled vicarious learning experiences in which teachers explicitly improved their teacher efficacy by observing their peers teaching using reform mathematics pedagogy. Second, it created the conditions for teachers to share frankly their between-session classroom implementation. These sharing sessions created new opportunities for teachers to recognize that they had been successful because of the instructional choices they made, resulting in more mastery experiences.

Essentially, this study illustrates that sustained professional learning programs that are collaborative and classroom-embedded support effective professional learning that leads to substantial student achievement gains and the related gains in teaching quality. Teacher efficacy can act as a further mediator to support higher student achievement. Teacher efficacy alone may have minimal impact, however, it operates indirectly by positively influencing teacher goal setting and persistence using challenging teaching strategies that benefit students. In contrast, high teacher efficacy based on untested or unchallenged self-appraisals can be disabling if teachers believe they have nothing new to learn from PL opportunities. In this study, the moderately high teacher efficacy coupled with the prior PL experiences and collaborative practices of participants in District A enabled goal setting, provided participants with a strong foundation for recognizing how the PL content was of value to them, and it provided participants with cultural capital in the form of capacity for collaborative learning.

The results have empirical implications for the long-term professional development efforts of teachers, and theoretical implications regarding teacher efficacy. Empirically, this study of a PL effort demonstrated that:

1. The teachers who were more experienced with the pedagogy being explored in the professional learning program, which in this case was teaching through problem solving, were able to maximize their learning from the PL program.
2. Far from demonstrating a ceiling effect, this study showed that these teachers were engaged in deepening their learning and applying it effectively to the classroom on an ongoing basis, while the teachers who were just beginning to learn about this type of pedagogy were mainly focused on surface features, such as the need to rely on grade level expectations instead of textbooks or trade materials, and the formal structures of co-teaching. These findings lend support to other research that has called for long-term, classroom-embedded, sustainable strategies that support teacher professional learning, rather than single workshops or professional learning programs that are disconnected from the classroom environment.
3. In-between-session activity of teacher participants where they implemented problem-based mathematics lessons regularly in their classrooms had a positive effect on teacher efficacy and related student achievement. Participant engagement in ongoing co-planning and co-teaching, beyond the six PD sessions was a key factor in the rate of participant feelings of success. Those participants who co-planned and co-taught between the formal sessions were more confident and engaged, as well as capable of implementing effective mathematics pedagogical practices by the end of the program.

Theoretically, the study confirms previous research indicating that:

1. Shifts in mathematics pedagogy require time and ongoing support in the form of authentic and collaborative professional learning opportunities that are supported and classroom embedded.
2. There is an indirect but powerful relationship between increasing teacher efficacy and increasing student achievement. We theorize that teacher efficacy, mediated by contextual factors, impacted what teachers learned from the PL opportunity, and how they learned.

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