ASSESSING THE EFFECTS OF COLLABORATIVE PROFESSIONAL LEARNING: EFFICACY SHIFTS IN A THREE-YEAR MATHEMATICS STUDY

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In a three-year study of teacher professional learning in Ontario, Canada, researchers examined the outcomes of collaborative inquiry in mathematics on teacher efficacy, student efficacy and achievement. The study applied a mixed methods approach involving over 1000 teachers and their students as well as case study sites in French and English. The Ministry of Education funded professional learning program (CIL-M) focused on teacher collaboration, mathematics knowledge for teaching, and student mathematical thinking. Findings indicate that the CIL-M professional learning program, which was refined annually based on researcher recommendations, resulted increasingly stronger teacher efficacy results, leading to related positive student beliefs and achievement.

Background

The Ministry of Education in Ontario, Canada launched a program to strengthen the capacity within district school boards to improve teaching and learning in K-6 mathematics. Key elements of the Collaborative Inquiry for Learning in Mathematics (CIL-M) initiative included classroom-embedded mathematics professional learning, mathematics content learning, facilitation of school and district-level professional learning networks, peer coaching, and increased leadership capacity in math education. External researchers were commissioned to assess the effects of the CIL-M program beginning in 2008 and continued to collect three years of data. Researchers focused on teacher efficacy as well as student efficacy and achievement.

The inquiry-based professional learning (PL) model involved a vertical slice of classroom teachers, special education teachers, consultants/coordinators, school effectiveness leads, and principals in district school boards across Ontario. Trained facilitators worked with teams of participants in pairs of co-terminus districts, both in English and French language schools in district school boards. Although the participants were different in each year of implementation, the PL was relatively consistent from 2008-09 through to 2010-11, and focused on: i) Mathematics communication in the classroom; ii) Teaching and learning mathematics through problem solving; iii) Enactment in classrooms (where participants try out a range of instructional strategies appropriate to the content, and then analyse student work samples, in discussion); iv) Teacher selection of learning goals and development of high quality lessons (with facilitators) that elicit student communication and inquiry; and, v) Collaborations (both structural and pedagogic) within classrooms, schools, district school boards, paired district school boards, and with the Ministry of Education personnel. The major activities of the participants involved co-planning, co-teaching and debriefing as a form of collaborative inquiry.

Objectives

Two central research questions for this study were: 1. What is the impact of the CIL-M Professional Learning model on teachers' professional beliefs and instructional practices? and, 2. What is the impact of teachers' beliefs and practices on student achievement and beliefs about mathematics learning?

Theoretical Framing

Teacher efficacy

Teacher efficacy is a teacher's belief that he or she has the ability to influence student learning (Bandura, 1997). Thirty years of research related to teacher efficacy (Bruce & Ross 2008; Ross & Bruce 2007;Goddard, Hoy & Woolfolk Hoy, 2004; Tschannen-Moran, & Woolfolk Hoy, 2001; Tschannen-Moran, Woolfolk Hoy & Hoy, 1998; Ross, 1998; Bandura, 1997;Gibson & Dembo, 1984) indicates that teachers who believe they are capable of supporting student learning, persist longer with challenging teaching strategies even when faced with obstacles (such as child poverty or student learning disabilities) and are more likely to experiment with high-yield instructional strategies including student-centred learning approaches (Riggs & Enochs, 1990) and problem-based lessons in mathematics (Bruce, et al, 2010). A teacher with low efficacy believes that circumstances such as socio-economic status of the students or availability of resources, are significantly more powerful influences over student learning and achievement than his or her teaching. Importantly, high efficacy teachers produce higher student achievement (Bruce, et al. 2010; Herman, Meece, & McCombs, 2000; Mascall, 2003; Moore & Esselman, 1994; Muijs & Reynolds, 2001; Ross, 1992; Watson, 1991), use effective classroom management strategies that support self-regulation, and build student confidence (see review in Ross, 1998).

Bandura (1997) identified four important sources of efficacy information which, in order of strength are: mastery experiences, vicarious experience, social and verbal persuasion, and physiological and emotional cues. Mastery experiences, the most powerful source of efficacy information, emerge when the teacher has a particularly successful teaching experience in the classroom where there is clear evidence from students that his or her teaching has supported increased student understanding and/or achievement. The three other sources of efficacy information identified by Bandura relate to opportunities to watch others of a similar skill level have mastery experiences (vicarious experience); the influence of peers and others in conversation with the teacher (social and verbal persuasion); and, feelings and reactions the teacher experiences during and after teaching situations (physiological and emotional cues). The teaching context plays a key role in teacher self-appraisals:"[I]n making an efficacy judgment, consideration of the teaching task (and its context) is required" (Tschannen-Moran M. & Gareis, C.,2004, p. 574). Teacher efficacy is relatively stable once established. It takes a strong disruption of current practice norms for a teacher's sense of efficacy to shift (Tschannen-Moran, M., Wolfolk Hoy, A., & Hoy, W. K., 1998). One way to disrupt efficacy levels is to provide high quality, powerful, professional learning experiences (Bruce et al, 2010).

What do we mean by “powerful professional learning experiences?

There are extensive lists of important characteristics for professional learning. Guskey (2003) reviewed 13 such lists, finding there was little agreement among them. In contrast, Hill’s (2004) review found eight features that consistently distinguished effective PL in mathematics education. These standards, which were adopted for this study, are listed here in a non-hierarchical order: (i) active inquiry in which teachers develop their understanding of mathematical concepts by solving problems for themselves; (ii) analysis of examples of classroom practice delivered through video, examples of student work or curriculum materials; (iii) collaboration among teachers while they are engaged in professional learning; (iv) PL presenter modeling of exemplary practice; (v) in-school application of PL ideas by teachers followed by reflection and feedback during the PL session; (vi) focus on appropriate math content and how to teach it; (vii) focus on student learning, including how to present content to students, developing knowledge of student misconceptions, and understanding how math thinking develops in learners; and, (viii) teacher choice in identifying the professional learning needs to be addressed in the PL and the mode of PL delivery.

Why is teacher collaboration (including co-planning and co-teaching) important?

Hill’s third criterion for effective professional learning is teacher collaboration. Teacher collaboration, within and among schools, contributes to student achievement in mathematics because of the opportunities it provides for joint professional learning (Goddard, Goddard, & Tschannen-Moran, 2007). Collaborative learning has additional benefits, such as an increased willingness of teachers to share control of math discourse with students, greater use of challenging math tasks, careful listening to students’ mathematical ideas, and the development of higher expectations for student performance (Borko, Davinroy, Bliem, & Cumbo, 2000). The impact of PL is magnified when teachers participate with colleagues from the same school or district (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007) to increase shared ownership and accountability (Bruce et al, 2010).

Participation in collaborative inquiry has also been found to have a positive effect on teacher efficacy (Bonner, 2006; Bruce & Ross, 2009; Henson, 2001; Ross, Rolheiser, & Hogaboam-Gray, 1999), improves teacher attitudes toward research (Bruce & Ross, 2009, Cousins & Walker, 2000; McDonough, 2006), and contributes to further teacher support for collaboration (Capobianco, 2007; Lytle & Cochran-Smith, 1990; McDonough, 2006). Collaborative inquiry also contributes to teacher gains in subject knowledge (e.g., Buck, Latta, & Leslie-Pelecky, 2007), pedagogical content knowledge (e.g., Bonner, 2006; McDonough, 2006; Wagner, 1999), and general pedagogical knowledge (Capobianco, 2007).

Method

The study was an effectiveness study, i.e., one that provided in-service to typical teachers working in typical conditions, rather than an efficacy study that provided training to a specially selected cadre of outstanding teachers working in ideal circumstances. (For more information about the differences between effectiveness and efficacy studies, see Seligman, 1995.)

In all three years of the study, the research team used a mixed methods design (Creswell, 2008; Creswell & Plano-Clarke, 2007) with the third year focused on confirming the previously positive results in achievement and efficacy for Junior Grade teachers and students, but also focused on gaining greater insight and depth of understanding of what phenomena were occurring for teachers and students to contribute to these gains. In this way, the grain size of the research was continually refined to examine how teacher professional learning in mathematics can influence the quality of mathematics education. (See methods in table 1)

Table 1. Overview of Methods

Yr	Research Questions	Research Methods, Populations, Data Sources
1	What are the effects of CIL-M on student achievement, teacher efficacy, and student efficacy?	• Mixed methods (pre and post surveys and achievement tests; classroom and PL observations; interviews) • Treatment group only • Participants: 15 school districts, 86teachers, over 500 students
2	What are the effects of CIL-M on student achievement, teacher efficacy, and student efficacy in two situations: a. Replication (can effects be replicated in a second year?) b. Sustainability (can effects be sustained beyond formal PL year?)	• Mixed methods (pre and post surveys and achievement tests; classroom and PL observations; interviews); • Treatment group & Control group • Participants: 18 districts and 4 case study sites; 110 teachers, just under 1000 students
3	Why is it working? Fine grained view in case study sites (French and English) And, what are the effects of explicit attention to student beliefs?	• Mixed methods (emphasis on qualitative case study methods – interviews & classroom and PL observations; sample teacher and student efficacy data; sample student achievement data for confirmation of continued effects) • Participants: 52 teachers, 639 students

Results

In 2008-2009, the research team found positive effects of CIL-M on teacher efficacy and student efficacy with modest accompanying achievement gains. Because increased efficacy is a predictor and precursor to increased achievement (Bandura, 1993), the research team predicted that gains in year two would be further elevated in the area of achievement data. This prediction was confirmed. Of particular importance in 2009-2010 was the finding that those school districts that sustained their inquiry-based professional learning into a second year had even greater efficacy and achievement gains in their second year. Researchers then recommended that districts continue to be supported in their sustaining efforts with inquiry-based professional learning in mathematics, and that the 2010-2011program be amplified to provide even greater attention to strategies for strengthening student beliefs. Following these recommendations, professional learning activities in the CIL-M program in 2010-2011 focused attention on student beliefs. Corresponding research activities examined the impact of the PL program on teacher beliefs and related instructional approaches in mathematics, and, further, examined how these affected student beliefs about math learning. Again, the effects were positive. The results in this paper focus on teacher efficacy in particular.

Quantitative Findings

Table 2 summarizes the teacher efficacy results over three years. The first column identifies the features of teacher efficacy measured. Column two provides control group data. Columns three, four and five show the data for English language teachers across the three years. The final two columns show French teacher data in the first two years (French teacher data were not collected in year 3). The cells of the table show the effect sizes (Cohen's *d*) for each group in each year. The effect size is the difference between pre- and post-test scores, divided by the pooled standard deviation. An effect size of zero indicates that a program had no effect on participants. The final row of the table shows the mean effect averaged over the four outcome measures.

Table 2. CIL-M Effect Sizes* by Year and Language

Teacher Outcome	Control	English Teachers			French Teachers	
	2009-10 (*N*=844)	2008-09 (*N*=77)	2009-10 (*N*=38)	2010-11 (*N*=52)	2008-09 (*N*=11)	2009-10 (*N*=43)
Math Teaching Practices	0.13	0.40	0.35	0.76	0.75	0.33
TE: Engagement	0.02	0.22	0.38	0.19	0.63	0.32
TE: Instructional Strategies	0.13	0.41	0.34	0.72	1.11	0.44
TE: Classroom Management	0.04	0.18	0.23	0.08	0.79	0.84
Mean Effect	0.08	0.30	0.33	0.44	0.82	0.48

Note: TE=Teacher Efficacy * Effect Sizes measured using Cohen's *d(small ES approx. 0.2, mid ES approx. 0.5, large ES approx.. 0.8)*

Table 2 illustrates how teachers in each year of the CIL-M program, learned more than teachers in the control condition. Program outcomes were 4 to10 times greater than the outcomes of the control population. The table also shows that for the English teachers the program became more effective over time. The opposite was the case for the French teachers, but the French teacher data may be misleading as it involves a very small number of teachers who participated in the 2008-09 data collection.

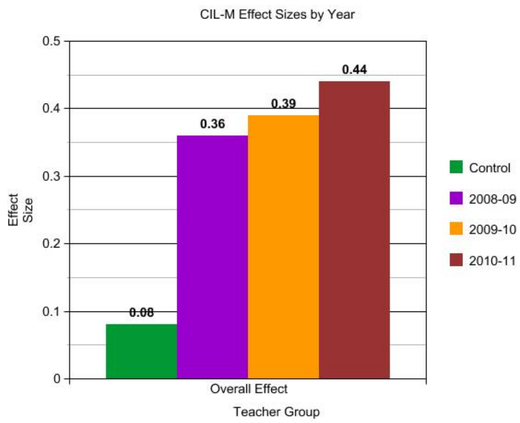

Figure 1. Teacher Efficacy Outcomes Over Three Years

In Figure 1, the results for French and English teachers in each year of CIL-M were combined and compared the results to the control group. The Figure shows the distinct advantage of CIL-M over the control group in each of the three years of the program and provides evidence that the impact of the PL program increased each year.

Although the main focus of CIL-M was the professional renewal of teachers and related efficacy, each year data were collected on student outcomes as well. The general pattern was a gradual increase from year 1 to year 3 of the program. For example, the impact of CIL-M on Primary students' confidence in their math ability increased from *d*=0.29 in 2008-09 to *d*=0.55 in 2010-11. Primary students' fear of failure declined more in year 3 than in year 2 (*d*=-0.15 in 2008-09 and *d*=-0.39 in 2010-11) while the positive impact of CIL-M on Primary students' self-reported effort was the same in the first and last year of the evaluation (*d*=0.28).

Students in classrooms taught by participating teachers also improved from pre to post-achievement tests on virtually all measures in all grades. The gains were especially large on the open-ended measures in grades 3, 4 and 5 and on the multiple-choice items in grade 6. The student achievement impacts were much larger in 2010-11 than in 2009-10. When aggregated across all classes taught by CIL-M teachers, the impact on open-ended and multiple-choice assessments was small but positive (*d*=.02 to .08).

Qualitative Case Study Findings

Researchers collected field note data of PL sessions, classroom teaching and co-teaching opportunities, as well as audio and video data of focus group interviews, individual formal interviews and informal discussions and lesson artifacts. Table 3provides a summary of the types and quantity of data collected. In the case study research (Yin, 2009) and cross-case analyses, the research team was able to document the phenomena of teacher and student learning, as well as identify the favourable conditions that enabled the process for developing positive beliefs and practices.

Table 3. Approximate Number of Documents Across 3 Year Study

Type	Number of documents	Pages
Field notes of PL sessions	130	1000+
Co-teaching observations	75	260
Interview Transcripts	320	1440
Artifacts, Photos, Video	1000+ from CIL-M and co-teaching sessions	770
	1625	3470

The most influential positive conditions of teacher learning identified through coded interview and observation data as well as through survey data were (in order of teacher-reported importance) opportunities to:1. Implement problem-based lessons with support; 2. Engage in live classroom observations and listening to students talk; 3. Develop content knowledge in mathematics; and 4. Practice high-yield strategies such as using manipulatives, anticipating student problems and identifying strategies for relieving misconceptions.

Participating teachers described important characteristics of the professional learning program that supported their learning. The two most powerful were: 1. The classroom embedded nature of the PL program where participants spent time together in classrooms and with students both during formal PL sessions and between-sessions in smaller working groups; and 2. The high level of collaboration amongst participants, including productive norms for co-planning lessons and co-teaching activity in order to carefully consider instructional strategies and the mathematics content.

The qualitative data helped researchers capture the overall phenomenon of the CIL-M program and its effects. Researchers generated the following explanatory diagram based on year 1 and year 2 (2008-2010) findings (see Figure 2). The model was then tested in year 3 and found to be consistently accurate.

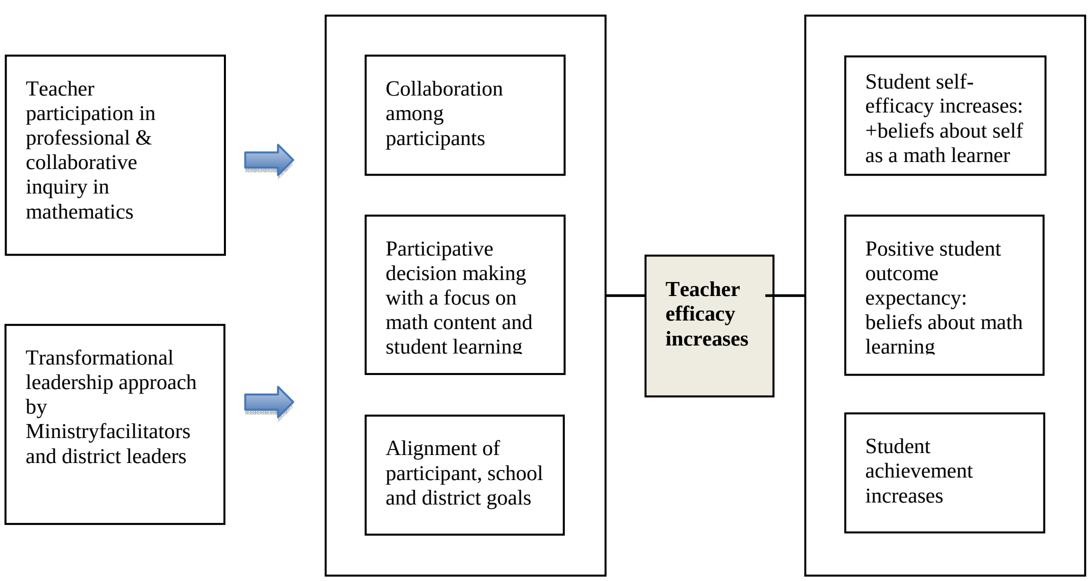

Figure 2. Program Process Theory: Efficacy development in the collaborative mathematics professional learning program

Teacher participants in the collaborative inquiry program were empowered to make instructional decisions collaboratively and to explore mathematics content more deeply. As teachers explored instructional practices that focused on student inquiry in mathematics and communication of ideas, there were shifts in teacher perspectives about how students learn mathematics. These shifts led to more functional believes about student learning, higher expectations for students, and greater emphasis on communication by and for students. This in turn translated to increases in student efficacy, confidence, and engagement in mathematics. When students had mastery experiences in mathematics, participating teachers observed these and in turn, had mastery experiences themselves as teachers. Observations of colleagues co-teaching in the classroom also supported vicarious experiences that contributed to efficacy information for participants. The increased efficacy of these teachers led them to incorporate high-yield but challenging instructional strategies on a regular basis. As a result, students increased their self-efficacy, and positive beliefs about mathematics which began to translate into increases in student achievement.

Discussion

In summary, the three-year study found that professional learning delivered through the collaborative inquiry in mathematics program (CIL-M) had a positive effect on teacher efficacy, as well as student beliefs and achievement. The benefits of participating in the CIL-M program in 2008-09 more than maintained with new populations of teachers and students into 2009-10, and then further improved with new populations of Junior Grade teachers and students in 2010-2011. The additional gains for new populations from year-to-year may be attributed to refinements that were implemented in the professional learning program each year, based on recommendations made in comprehensive annual reports to the Ministry of Education.

Although program features (such as engaging teachers in the collaborative lesson development, co-teaching and collective reflection on lessons that focus on deep student understanding of important mathematical ideas) could be incorporated into a broad range of professional learning activities, including those that are completed in short periods, it is important to underline that learning takes time. A key reason why the CIL-M program was successful is that substantial PL time (10-12 sessions including between-session implementation) was allocated to each teacher team. Previous research (summarized in Desimone, 2009) demonstrates that teachers need at least 20 hours of contact time to develop and maintain new instructional strategies. The research team suggests that distributing scarce resources across a large number of teachers is likely to be less cost-effective than concentrating professional learning activities in a small number of sites committed to instructional improvement.

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