A MODEL FOR INCREASING REFORM IMPLEMENTATION AND TEACHER EFFICACY: TEACHER PEER COACHING IN GRADES 3 AND 6 MATHEMATICS

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This study examined the effects of peer coaching on mathematics teaching practices and teacher beliefs about their capacity to have an impact on student learning. Twelve teachers in grades 3 and 6 participated in a brief but intensive professional development program over six months. The program focused on effective mathematics teaching strategies and peer coaching opportunities. Data sources included classroom observations, teacher self-assessments, interviews, and field notes. Data were analysed using a two-level qualitative coding strategy with multiple interpreters. Findings showed that teachers implemented key strategies for effective mathematics teaching, especially in facilitating student interaction and improving the quality of tasks assigned.

Key words: mathematics, teaching strategies, professional development

Cette étude a trait aux effets de l'enseignement mutuel en mathématiques sur les méthodes pédagogiques des enseignants et leurs croyances quant à leur capacité d'avoir un impact sur l'apprentissage de leurs élèves. Douze enseignants en 3[e] et 6[e] années ont participé à un programme de perfectionnement intensif sur une période de six mois. Le programme était axé principalement sur des stratégies efficaces pour l'enseignement des mathématiques et les possibilités d'enseignement mutuel. Les sources des données étaient multiples : observation de la classe, auto-évaluation de l'enseignant, entrevues et notes prises sur le terrain. Les données ont été analysées à l'aide d'une stratégie de codage qualitatif à deux niveaux avec de multiples interprètes. Les résultats indiquent que les enseignants ont mis en œuvre des stratégies clés pour enseigner efficacement les mathématiques, notamment en facilitant les interactions entre les élèves et en améliorant la qualité des tâches assignées.

Mots clés : mathématiques, stratégies pédagogiques, perfectionnement professionnel.

Teacher peer coaching is an intensive professional development (PD) activity in which teachers provide one another with feedback about their teaching. This study measured the effects of peer coaching and related mathematics in-service with 12 teachers in grades 3 and 6. We focused on shifts in instructional practice and teachers' beliefs about their instructional capacity to teach mathematics.

THEORETICAL FRAMEWORK

Teacher Efficacy

Our conception of teacher change is grounded in social cognition theory (Bandura, 1997). Teacher efficacy is a type of self-efficacy. Self-efficac*y* is the belief "in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 2). Self-efficacy affects behavior by impacting goals, outcome expectations, affective states, and perceptions of socio-structural impediments and opportunities (Bandura, 1997). Individuals who feel that they will be successful on a given task are more likely to be so because they adopt challenging goals, try harder to achieve them, persist despite setbacks, and develop coping mechanisms for managing their emotional states.

In this framework, teacher willingness to experiment with instructional ideas, particularly techniques that are difficult to implement, depends on teacher expectations about their ability to influence student learning. Those teachers who believe they have the ability to affect student learning and achievement positively are more willing to implement challenging strategies to achieve their goals with students. Teachers' absolute level of classroom success has less influence than their interpretations of experiences on subsequent action because teacher confidence in executing difficult tasks in the near future deter-mines how effectively a teacher employs his or her capabilities (Tschan-nen-Moran, Woolfolk Hoy, & Hoy, 1998).

Research in the area of teacher efficacy has produced a solid body of literature that focuses on how teachers judge their own capacity to bring about student learning. Teacher efficacy constitutes a set of expectations that contribute to student achievement (Ross & Regan, 1993; Ross, Bruce, & Hogaboam-Gray, 2006; Mascall, 2003; Muijs & Reynolds, 2001), teacher motivation (Guskey, 1984; Midgley, Feldlaufer, & Eccles, 1989), persistence in achieving goals, and retention of teachers in the profession (evidence reviewed in Ross, 1998). Teacher efficacy contributes to achievement because teachers with high efficacy use effective classroom management strategies to encourage student autonomy, meet the needs of low ability students, and positively influence student perceptions of their abilities (evidence reviewed in Ross, 1998).

Over several years of research, we developed and tested a model of teacher change (see Ross, Bruce, & Hogaboam-Gray, 2006) in which teacher efficacy is the central mediator between experience and action. Our teacher change model illustrates a series of activities and relationships that influence how teachers judge their capacity to impact student learning and achievement, set goals, and persist in meeting those goals.

When a teacher is dissatisfied with current performance (based on student expressions of achievement and teacher self-assessment), there is a perceived need for instructional change. When a teacher has access to powerful alternatives (through effective professional development opportunities, for example), he or she has the means to make changes. If a teacher is sufficiently motivated to sustain efforts and overcome obstacles (has high efficacy), the ability to implement effective instructional strategies is increased. Further, when a teacher receives positive and constructive feedback from a respected peer, there is even greater potential for enhanced goal setting, motivation to take risks, and implementation of challenging teaching strategies. Without providing the entire model, Figure 1 illustrates what we believe to be the core activity and relationships involved in this process.

Our focus for this article is the left side of the model. Our goal is to document the effects of peer input and professional development promoting innovative instruction on the implementation of effective mathematics teaching strategies and teacher efficacy.

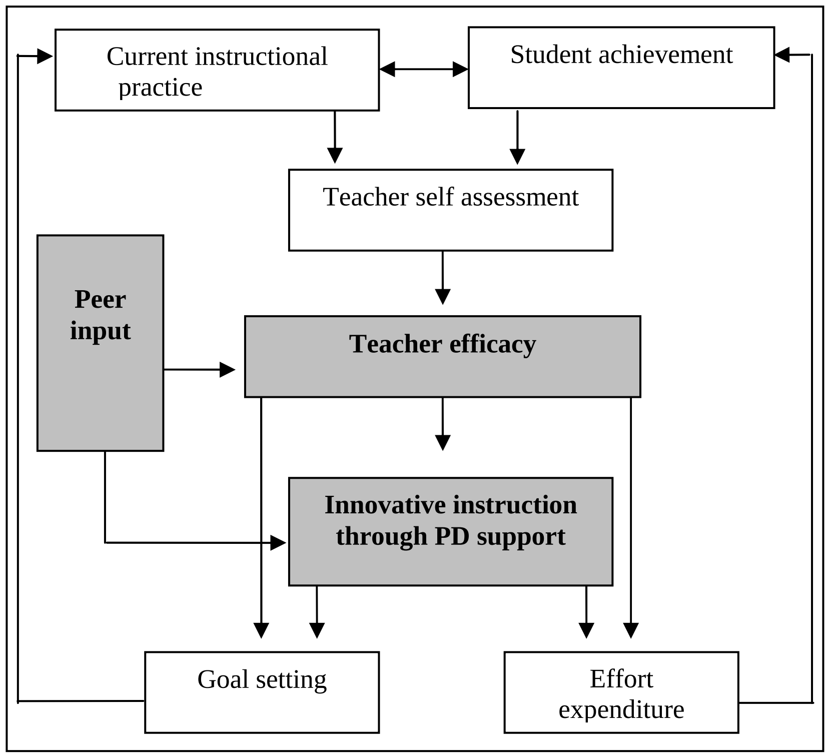

Figure 1. Model of Teacher Change: Activities and Relationships That Influence Efficacy

Of the four sources of teacher efficacy information identified by Bandura (1997), the most powerful is mastery experience – first-hand teaching experiences. Teacher perceptions of changes in student performance gleaned from student utterances, work on classroom assignments, homework, and formal assessments all provide information to teachers that informs their self-judgments. Bandura (1997) defined three other sources of efficacy information: vicarious experience – teacher observations of peers of similar experience levels; social and verbal persuasion – encouragement, support, and feedback from colleagues and supervisors; and physiological and emotional cues – how a teacher is feeling about teaching and learning situations. These additional three sources of efficacy information have been found to be less influential compared to mastery experience (as reviewed in Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998). What appears to be less clear in the research to date is the nature of interaction among the four sources of efficacy information.

INFLUENCE EFFICACY

Goal Setting and Effort Expenditure

Goals and effort are linked. For example, teachers are more likely to persist if they set goals that are specific, have clear outcomes, are achievable in the near future, and are moderately difficult to achieve (Schunk, 1981). The combination of goals and effort affect teacher practice, including choice of curriculum objectives, teaching methods, assessment practices, and knowledge of subjects, learners, pedagogy, and policy. Teachers willing to try new instructional ideas and persist through obstacles are more likely to sustain the implementation of new approaches, to experience success, and to integrate the innovations into their practice.

Peer Coaching

Teachers experience norms of privatized practice with limited opportunities for peer input because of the nature of the physical space, administration, schedules, and structures of most schools. Creating professional school communities can help to overcome isolation through the facilitation of shared values, collaborative decision making, and reflective dialogue (Louis & Marks, 1998). A structured approach for building such a community is peer coaching in which pairs of teachers of similar experience and competence observe each other teach, establish improvement goals, develop strategies to implement goals, observe one another during the revised teaching, and provide specific feedback. This approach requires a safe and collegial environment (McLymont & da Costa, 1998). In a review of peer coaching literature, Greene (2004) found that teachers in peer coaching programs were more successful than control group teachers in implementing new instructional strategies, using the new strategies in more appropriate ways, sustaining the use of new strategies, and understanding the purposes of instruction. Peer coaching also contributes to increases in teacher efficacy (Kohler, Ezell, & Paluselli, 1999; Licklider, 1995).

When teachers make self-assessments about the quality of their teaching, peer input can influence these self-judgments in multiple ways. Peers can direct teachers' attention to particular dimensions of practice and to the level of goal attainment. Further, peers can influence teachers' practice by attempting specific strategies concurrently. These opportunities for positive peer influences involve recognizing teaching success (valid mastery experiences). Peers can also influence teacher efficacy through the three other sources of efficacy information proposed by Bandura (1997): social persuasion (persuading peers that they are capable of performing a task), vicarious experience (observing a similarly capable teacher peer implementing successful strategies), and physiological and emotional cues (peer influence on increasing positive feelings arising from teaching and teaching ability or on reducing negative feelings arising from teaching experiences).

Peer coaching has not been found to be universally successful. Perkins (1998) found that teachers had difficulty with the specific communication skills associated with peer coaching. For example, peer coaching teachers rarely asked open-ended questions of peers, did not paraphrase to check for common understanding, and made limited use of helpful probes. Busher (1994) reported a study of teachers who were randomly assigned to peer coaching and control groups. Training consisted of sessions on questioning skills, nonverbal communication, support strategies, and thinking skills. The treatment had no effect on instructional practice, most likely because there was no attempt to provide teachers with content specific instructional skills. These findings suggest that an effective peer coaching program needs to combine training of the peer coaching process with content specific pedagogy training.

Content Specific Pedagogy Training

We based our in-service program on the Professional Development Standards for Elementary Mathematics (Hill, 2004). Consequently, teachers engaged in mathematics tasks and content comparable to those undertaken by their students; the in-service focused on classroom practice (such as teachers examining student work samples); in-service tasks required teachers to work collaboratively; in-service presenters modeled recommended instructional practices; the in-service illustrated how students learn mathematics; and teachers participated in the design and delivery of the in-service. These standards each contribute to teacher learning (Erickson & Brandes, 1998; Garet, Porter, Desimone, Birman, & Yoon, 2001).

Through the professional development program, we urged teachers to reconsider what constitutes effective teaching and learning in mathematics. Instead of defining a lesson as successful if most students obtained the right answer on procedural questions using conventional algorithms, we demonstrated how teachers could focus on the depth of conceptual understanding that students reached and on the extent to which students contributed to the construction of their knowledge as they developed solutions to rich tasks. The central tool to support this process was a rubric for mathematics teaching that focused teachers' peer observations and their improvement goals on dimensions of mathematics teaching of highest priority to subject experts.

We developed a descriptive tool from a research synthesis (Ross, McDougall, & Hogaboam-Gray, 2000) and the National Council of Teachers of Mathematics (NCTM) policy statements (NCTM, 1989, 1991, 2000) that identified 10 dimensions of effective mathematics teaching (standards-based teaching). The rubric was constructed from observations and interviews with teachers who ranged from traditional to innovative (Ross, Hogaboam-Gray, McDougall, & Bruce, 2002). For each of the 10 dimensions, we identified four levels, arranged in order of increasing fidelity to NCTM standards. The validity of the hierarchy of levels was established by a panel of content experts and by a series of studies that tested the validity of a self-report survey and the related rubric (Ross & McDougall, 2003).

We selected three dimensions of effective mathematics teaching for special attention: facilitating student-student interaction, supporting student construction of mathematical meaning, and selecting effective mathematics tasks. In the professional development sessions, experienced teachers modeled effective teaching using grade-appropriate, engaging mathematics tasks. Presenters encouraged teachers to judge their success in terms of familiar standards, such as students' use of appropriate mathematical language, and less familiar standards, such as students' invention of problem-solving procedures, as well as students' sharing of explanations and justification of solutions. When debriefing between-session practice, we concentrated on these newer standards for teacher self-assessments of success. In this way, we reduced teachers' perceptions of the difficulty of the instructional tasks and increased their belief in their ability to teach in new ways.

METHOD

In-service Design

In this study, we designed a four-session in-service series to direct peer attention to instructional decisions and enhance content related pedagogical practices, increase the implementation of reform-based mathematics teaching, and enhance teacher perceptions of their ability to improve learning using a reform curriculum. The key challenges were reducing teacher isolation through peer coaching opportunities (funded by Ministry of Education grant money) and providing teachers with both the conceptual and strategic tools to move toward mathematics reform implementation as well as the skills to participate effectively as peer coaches.

The two-pronged approach of providing peer coaching training and mathematical pedagogy training required in-service that explicitly addressed each of these components. For example, each PD session began with training on peer coaching techniques (such as how to set up a peer observation situation so that the peer observing would focus on an articulated goal set by the observed teacher) and a debriefing of the between session peer coaching activity for each peer coaching pair (with specific prompts to guide the discussions). Later in the same PD session, discussion of a specific dimension of mathematics teaching, such as student construction of mathematical ideas was introduced and followed by specific mathematics tasks that successfully illustrated how to implement this dimension with students. The two components of the in-service overlapped frequently. For example, teachers were engaged in examining the area of a triangle made with an elastic on a pegboard. Participants were asked to use elastics to create other non-congruent triangles on the pegboard with the same area as the first triangle. With their peer coaching partners, teachers explored creative ways to determine area without using a formula and problem solved to construct other non-congruent, same area triangles. When this lesson was concluded, participants were asked to analyse what the teacher did and why the teacher made those particular "teacher moves" during the lesson as well as what they, as learners, were doing and thinking. Participants noted that the "teacher" provided an open-ended problem with multiple solutions and solution strategies. The "teacher" modeled the first triangle as a given but did not lead "students" to an answer. Instead, the "teacher" encouraged partners to work together to explore possible solutions. Participants also noted that they needed partner discussion and physical manipulation of the elastics to arrive at solutions. This practice provided insight into how children construct mathematical understanding, effective mathematics pedagogical practices, and opportunities for the peer coaches to interact as co-learners.

Study Participants

Participants were four pairs of grade-3 teachers and two pairs of grade-6 teachers. The 12 teachers were volunteers and reflected a range of mathematics teaching styles from traditional to reform.

Data Sources

Teacher Observations. All 12 teachers were observed at the beginning and end of the project (over four individually teacher developed mathematics lessons of approximately 50 minutes each per teacher) with regard to the three teaching dimensions that were central to the in-service: *selection of mathematics tasks*, *student construction of mathematical knowledge*, and *support for student-student interaction.* We trained five observers in the use of the Classroom Observation Guide (Ross & Bruce, 2007), which provides guidelines for observing and recording field notes, and a definition of each of the three dimensions of mathematics teaching, along with specific probes to guide the process of collecting information. Observers recorded detailed examples of teacher actions relevant to each dimension. The observer training sessions emphasized the importance of rich descriptions of teacher practice, consistency in application of the observation template, and collecting sufficient information to make a confident placement decision on the four-point scale for each rubric dimension.

Online Self-Assessment. Teachers completed an online assessment at the beginning and the end of the study. The assessment provided a global score representing commitment to effective teaching, reflecting the three focus dimensions of the PD program as well as seven other dimensions of effective teacher practice.

Peer Coaching Summaries. Each teacher was observed by his or her peer on three occasions. Each pair compared peer observations to self-perceptions, negotiated improvement goals, devised strategies to implement goals, and provided feedback on instructional changes. Each teacher brought a summary of the peer coaching experience to the following in-service. The first page contained six prompts to establish whether peer coaching had been implemented:

Did you . . .

- Observe your partner teaching math?
- Talk to your partner about what you saw?
- Get feedback from your partner about what he/she saw?
- Help your partner set his/her math teaching goals?
- Get help from your partner in setting your math teaching goals?
- Set a date for your follow up observation?

The remaining two pages were used to facilitate conversations between the peers in discussing observed teacher activity, identifying what went well in their teaching, and identifying what they planned to do next (setting goals).

Pairs Interviews. At the conclusion of the study, each teacher pair was interviewed by a researcher. The interview guide focused on teacher perceptions of change in practice, the identification of specific examples of teacher and student activity that illustrated reported changes in practice, and teacher rationales about which component(s) of the professional development program contributed to the change. All interviews were transcribed verbatim.

Field Notes of PD Sessions. Three researchers recorded their observations of in-service activity in field notes that were compiled at the end of each session.

Data Analysis

The first level of the analysis focused on descriptive questions:

- Was the treatment implemented?
- Did the treatment have an effect on teacher practice?
- Which elements of the treatment had the greatest impact on teachers' instructional practice and beliefs about their capacity (teacher efficacy)?

The second level of analysis used pattern matching (Mark, Henry, & Julnes, 2000) in which we compared hypothesized to observed events to test the claim that self-assessment contributes to professional growth. In doing so we contrasted the mechanisms hypothesized in Figure 1 with a simpler model in which teacher change is attributed to providing teachers with information on how to teach mathematics from a standards-based perspective.[2] This simpler model assumes that teachers fail to implement reform mathematics because they lack pedagogical content knowledge, and that when this information deficit is filled, their practice will change. We treated each pair as a case and then compared across cases.

Credibility of the qualitative findings was enhanced by triangulating between data collection times (pre and post data collection) and interpreters (multiple observers and data analysts) (Creswell, 1998); maintaining an audit trail by creating charts of relationships and counting instances (Miles & Hubberman, 1994); and searching for evidence of alternative theories, i.e., testing the alternate hypothesis that provision of pedagogical content knowledge is sufficient for teacher change (Mark, Henry, & Julnes, 2000).

Although the number of cases was too small to make statistical significance tests meaningful, we found it helpful to calculate the means and standard deviations for each of the dimensions of effective teaching which we observed at the beginning and end of the study. These quantitative summaries contribute to the credibility of our cross-case claims.[3]

RESULTS

The coaching reports indicated that the teaching pairs successfully implemented the main steps of peer coaching during the three peer coaching opportunities. Participants observed their peers teaching mathematics, gave feedback to their partners on the observed lesson, received feedback from their partners on their own teaching, helped their peers set mathematics teaching goals, and were given help setting their own goals.

For this study, we report three key findings: first, teachers moved their practice toward standards-based methods; second, the professional development program had positive effects on teacher efficacy; and third, peer coaching caused participants to reflect more explicitly.

Finding 1: Teachers Changed Their Practice

The main finding of the study is that teachers shifted their mathematics teaching practices. Table 1 displays the means and standard deviations of the ratings of teacher practice by trained observers. The observers rated the teachers higher on the rubric for standards-based mathematics teaching at the end of the in-service than they did at the beginning of the study in all but one of the six dimensions/sub-dimensions.[4]

The observational data (summarized in Table 1) found that the 12 participants moved toward a more constructivist approach (student-directed, manipulatives-based, and conceptually-focused learning) in their abilities to facilitate student-student interaction (D3). By the end of the PD program, teachers were also more likely to assign open-ended and engaging student tasks that encouraged multiple solutions (D2). Although there were no pretest to posttest changes in construction of knowledge (D1) during observations, teacher reports of increased attempts to encourage student construction of mathematical meaning were explicitly detailed in peer interviews.

Previous research (reviewed in Ross, McDougall, & Hogaboam-Gray, 2000) found similar difficulties in supporting student construction

Table 1: Pre and Post Teacher Observation Ratings (*N=10-12)*

Dimension of Mathematics Teaching	Pretest		Posttest		t-test Results
	Mean	SD	Mean	SD	
D1: Construction of Knowledge	2.92	.76	2.96	.66	t(11)=-.290, p=.777
D2: Tasks: Multiple Solutions	2.75	.87	3.08	.82	t(11)=-.169, p=.120
D2: Tasks: Multiple Representations	2.46	.66	2.46	.72	t(11)=0, p=1.000
D3: Student-Student Interaction: Explicit Instruction (ES = .65)	2.40	.84	2.85	.82	t(9)=-.187, p=.095
D3: Student-Student Interaction: Task Assignment (ES = .94)*	2.75	.98	3.60	.84	t(9)=3.60, p=.006
D3: Student-Student Interaction: Communication (ES = .45)	2.45	.83	2.70	1.25	t(9)=-.86, p=.413

* p<.05

of mathematical knowledge. A key challenge is how much scaffolding to give to students. The handover of responsibility for knowledge construction to students is impeded when teachers excessively cue students and /or when teachers over-summarize what students supposedly learned in their discussions. One participant described this dilemma in her own practice:

I still struggle with this at times, is how much interference I have to have within the task. If I am wandering around, and they are on task, then I know that I am on the right track. But there are times where I have to stop and think. Like with a couple [of tasks] with probability. You need to focus on what they are looking for and they [the students] weren't following. That's a bit frustrating. Like I know I need to go back and re-look at that and organize it some other way. (interview, Kristi)

Our sense is that we need a more comprehensive strategy for supporting knowledge construction in mathematics classrooms with sustained focused professional development in this area.

The largest differences from pre to posttest observation were for student-student interaction. There are three subdimensions related to student-student interaction. When examining the subdimensions, the greatest improvement was for task assignment: posttest mean was almost a full standard deviation higher than the pretest mean (i.e., the pooled standard deviation was .87).

In interviews, participants attributed these changes in their practice to peer coaching *and* to the mathematical pedagogy training provided. It was not an either-or situation where one component was clearly more powerful than the other. The two prongs of the professional development program reinforced each other.

> I would say both primarily the peer coaching and the workshops at the board office: Those two kind of blended together there because we did get together, we saw each other there, we could chat even further about things that we were doing in the classroom in math. We sort of did some of that when we were together [at the in-service sessions] and took it a few steps further. It was great. (interview, Linda)

The professional development and peer coaching strategies caused four complementary effects: the peer coaching process awakened a desire for change; the in-service presentations provided explicit and effective models of alternate practices; the between session goal-focused activities provided opportunities for experimentation: and the debriefing conversations provided teachers with opportunities to understand how to integrate new practices into their existing styles. This four stage process reflects the model of professional reflection identified in Ross and Regan, (1993) where teachers experienced four stages embedded in professional reflection: dissonance, synthesis, experimentation, and integration.

Finding 2: Teacher Efficacy Increases Due to a Nexus of Sources of Efficacy Information

The second main finding of the study was that the professional development program had positive effects on teacher beliefs about their capacity as mathematics teachers. Interestingly, the efficacy information from mastery teacher experiences was strengthened because the other three sources of efficacy were more readily available. At the beginning of the in-service, some teachers experienced depressed confidence in response to the peer coaching and in-service program. For example, Laura found that the increased knowledge about "how conceptual math should be taught" generated in the project depressed her self-image because she was more aware of her shortcomings: "I am probably now consciously incompetent" (interview, Laura). Karen also found that her confidence initially declined because her aspiration level increased faster than her ability to meet it. "There were times at the beginning I thought, I need to do this in a different way now; I need to do this more in a more constructivist way [but] I'm not quite sure how to do that with this particular goal" (interview, Karen). As the in-service progressed, Karen found her confidence returning when she realized that she could implement ideas presented in the in-service to meet her goals.

Other researchers (such as Woolfolk Hoy, 2000) have documented this phenomenon of depressed efficacy at the onset of efforts to shift practice. However, by the end of the professional development program, teachers reported that they felt more confident and capable of teaching mathematics with an emphasis on conceptual understanding. Participants attributed this increase in efficacy to several facets of the PD program including validation by recognizing that some of their existing practices were similar to those modeled and recommended by presenters (vicarious experience), by receiving positive feedback from their peer coaching partners (social and verbal persuasion, physiological, and emotional cues), and by acquiring and successfully applying new instructtional strategies in their own classrooms (mastery experiences).

Some participants reported that peer coaching was a more successful approach than previous professional development experiences. For example, Jill reported that she had been trying for some time to persuade her partner, Nancy, to adopt a specific strategy for mental mathematics that worked well in Jill's class (interview, Jill). It was only when Nancy saw the method in action in Jill's class during the peer coaching observation that she decided to use it in her own classroom. By the end of the project, Nancy reported that she was using this same strategy regularly in her classroom (interview, Nancy). This example illustrates how multiple efficacy information sources worked together, because of the peer coaching conditions, to facilitate implementation of an effective teaching strategy: When Nancy heard about Jill's mental mathematical teaching strategy at the in-service, Nancy thought it sounded like a good idea. This example is a form of social and verbal persuasion. But Nancy did not immediately use the strategy herself. The verbal persuasion was insufficient on its own. Then Nancy watched Jill effectively use the strategy with students. The observation incident is an example of a positive vicarious experience where one peer gained deeper understanding of how to implement a teaching technique by watching a partner of similar experience and skill level. After seeing her peer successfully use the mental mathematical strategy with students, Nancy applied it herself and met with success, culminating in a positive mastery experience. This sequence demonstrates how peer coaching generates multiple positive sources of efficacy information to the teacher thus increasing the likelihood of implementation of more challenging pedagogical practices.

Other participants reported that vicarious experiences were particularly important. They were able to put their observations into immediate use. For example, Susan watched Karen teach a patterning activity, was deeply impressed ("I was in awe" [interview, Susan]), and then used the same lesson with her own students. Susan was particularly appreciative of the opportunity to observe an experienced peer because, although a veteran teacher, Susan was teaching grade 3 for only the second time. Participants also reported that observing presenters, who were teachers, model innovative teaching strategies led them to believe that they too could be successful enacting standards-based teaching.

Teachers also described the impact of student expressions of learning as claims of improved teaching performance: enthusiasm, quality of student discourse, and student effort seeking multiple solutions. This evidence of increased mastery experiences was extensive and explicit. For example, Susan compared her previous year's students to this year:

> I wasn't getting that enthusiasm last year. I just wasn't. This year they are eager. Their eyes are on me. Their hands are up and they want to participate with the hands-on [materials] and for the most part they are on task. You do have those

kids that need a lot of [support] . . . oh I know, but they are doing a better job this year and maybe that means I'm doing a better job. (interview, Susan)

Intense Reflection

A less anticipated third finding was that participants were led to self-reflect more frequently and explicitly because of the interaction with their coaching peers. Participants reported that they normally had little time for conscious reflection on the success of lessons, beyond private ruminations that occur "on the fly . . . as you are driving home" (interview, Nancy). However, the peer coaching process removed the norm of isolation by providing a structured forum for teachers to share their interpretations of teaching experiences and receive feedback. For example, Helen observed William using a new text resource, which led her to think about how she might use text resources differently. Helen believed William's implementation was more advanced than hers, but she felt that she had incorporated some innovative elements into her teaching. Helen concluded that although she was not "following it as strictly as" William, she was on the right track (interview, Helen). Simultaneously, William was being questioned by his peer about his teaching decisions, leading William to question his own teaching: "I find myself questioning things that I am doing more and more . . . critically looking at the way I'm teaching and evaluating" (interview, William). Both Helen and William believed that self-questioning led them to implement higher quality instructional strategies. Meeta described her PD experiences as a reflective journey. She compared this professional development program to others, evaluating the current program as more powerful because it was personally relevant and focused on her mathematics teaching in particular. "I think [this PD was better] because this is more of a personal journey, a personal learning experience" (interview, Meeta).

Limits of the Peer Coaching Relationship

Because five of the six pairs involved cross-school groupings, some teachers had difficulty meeting and sustaining conversations about their teaching (field notes-S3). In these cases, peer coaching visits required considerable travel time. It is also possible that difficulty in the debriefing component of peer coaching was related to the expressed anxiety by some participants about being observed. For example, Nancy remembered asking herself during a peer observation lesson: "Why can't I understand what that student is saying? I bet Jill [the peer observer] knows what that student is saying" (field notes-S2). Further, some peers were reluctant to suggest substantive changes unless their partner suggested them first, or their partner specifically asked them to do so.

DISCUSSION

The professional development program had a positive impact on teacher efficacy and on teacher implementation of standards-based teaching. The combination of content-specific pedagogical training and peer coaching proved to be effective in supporting teachers in their implementation of innovative strategies.

Teacher judgments about their abilities to influence student learning were affected by the combination of efficacy information sources. Not only did teachers have positive mastery experiences using standards-based mathematics teaching and learning strategies (with more explicit selection of open-ended student tasks that encouraged multiple solutions and solution strategies), but they also received information about their success through peer interaction and observing models of teaching (social and verbal persuasion, vicarious experience, and physiological and emotional cues). The nexus of efficacy information sources reinforced one another to provide the participants with strong positive messages about their teaching which, in turn, encouraged further risk-taking and implementation of challenging strategies.

In returning to our model of teacher change, we believe that several directional adjustments to the diagram are required to represent the activity and relationships associated with teacher change. The revised model of teacher change (see Figure 2) reflects the findings of this study and further enhances our understanding of the reciprocal relationships created during the professional development process. Peer input influenced teacher efficacy and innovative instruction as predicted, but equally powerful was the influence of innovative instruction and teacher efficacy on peer input. That is, as teachers implemented standards-based mathematics teaching and increased their efficacy, the quality and importance of peer feedback was also increased.

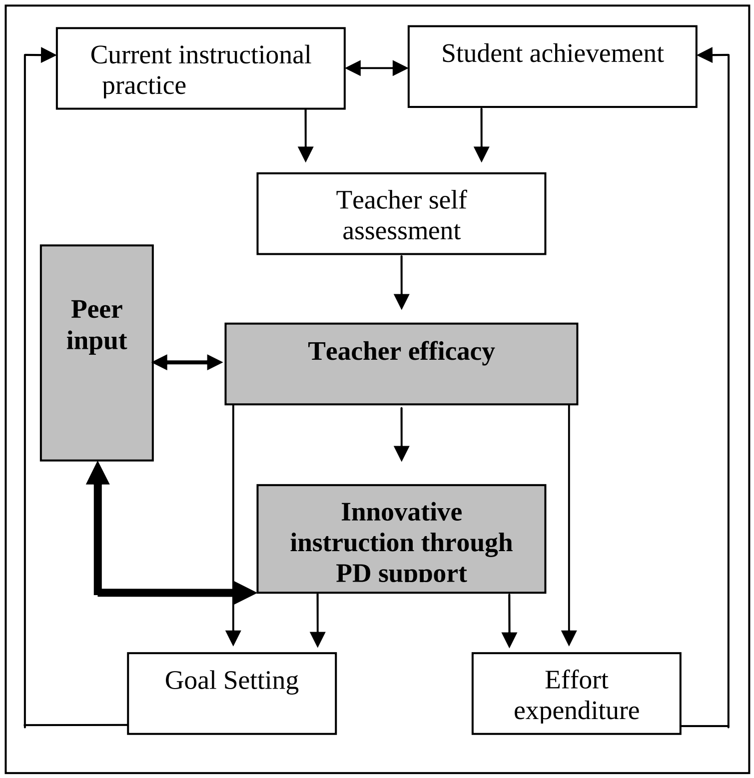

Figure 2. Revised Model of Teacher Change: Activities and Relationships That Influence Efficacy

This reflexive and reciprocal growth process is well illustrated in the paired interviews. For example Kristi explained that her motivation to take risks using innovative mathematics teaching strategies increased because she sought and received support from her peer coach.

> Having the peer, the person to talk to, to see what is happening in that class and that you're thinking the same thing. Or to question: I'll say [to my peer] I'm not sure if this is going work. I don't know. You are not plundering along on your own to see if you are on the right track. (interview, Kristi)

One pair combined peer input and innovative pedagogy to the point where they participated in two co-teaching situations to work through standards-based tasks with students:

Nancy: [peer coaching] never did happen before so it was just – to me that was a powerful experience to be able to go into each other's rooms.
Jill: And to watch each other teach. To watch Nancy teach math and to have her watch me was lovely. Especially that one day I was so sick and thank goodness she was here otherwise the lesson was going downhill fast because I wasn't making any sense and (laughter) . . . 'Gee I don't get this I just; oh thank goodness Nancy's here.' She saved that lesson.
Researcher: You did a little bit of co-teaching?
Jill: Oh totally. Because we are comfortable with each other, it was okay for us to step in. And for me to know I could hand out the manipulatives and go around and talk to the groups and I didn't feel uncomfortable doing that in her room and, I know she didn't feel uncomfortable doing that. So that it was more. It wasn't just watching. We definitely did co-teach. We might need to be in the same school
Nancy: I think [nodding in agreement]. (Jill & Nancy, co-teaching)

We believe that the revised model better reflects our findings in this study because it acknowledges the strong reciprocal links between peer input, teacher use of innovative strategies, and teacher efficacy. Although peer coaching models can be expensive in terms of release time for teachers to observe one another, we believe there are possible creative solutions to keep costs at a minimum and make this practice sustainable.

We recommend that the procedures used in this study be considered for professional development programs, but we also think they could be strengthened in several ways. First, we believe that a whole school approach has the potential to heighten implementation if teachers work in same-grade pairs embedded within a school staff. In this case, we recommend that the peer coaching process be linked directly to the school plan. Second, the treatment could be extended to five coaching sessions rather than three. For some teachers, the initial reaction to peer coaching was reduced confidence, which then rebounded over time. By extending the number of coaching cycles, there is greater potential to maximize teacher learning well beyond the confidence dip. The careful planning of these peer coaching sessions within the school context has the potential to reduce the costs of release time for teachers observing one another. For example, a school may be able to organize planning times so that they coincide to allow a pair of teachers to observe one another regularly during these planning times without additional costs.

Of interest for further research is the exploration of how teacher selection of open-ended tasks can be combined with emphasis on student construction of meaning. Although we have hypothesized in this study about possible reasons for the increased use of standards-based mathematics tasks and student interaction without evidence of increases in student construction of mathematical understanding, it is an area where further research is required, perhaps by examining teacher behaviours of "helping students" and how these behaviours facilitate or hinder student construction of meaning when using open-ended tasks. Finally, we suggest sharing more control with participants by inviting them to self-select goals of greatest importance to them from among the 10 dimensions in the self-assessment rubric.

In this study, teacher peer coaching provided a vehicle for intensive professional development for mathematics teachers. The effects of peer coaching combined with pedagogical training in mathematics proved to be a powerful strategy for moving teachers along a continuum of practices towards more effective teaching and learning opportunities. In the process, teacher engagement with peer coaching increased in terms of the quality and value of teacher collaboration. The interaction between peer coaching and effective mathematics teaching is a promising area for further study.

NOTES

[1] The research reported in this article was funded by the Ontario Ministry of Education and the Social Sciences and Humanities Research Council. The views expressed in this article do not necessarily represent the views of the Ministry or the Council.

[2] Standards-based mathematics involves teaching toward specific skills, concepts, and knowledge students should learn at each grade level. Standards-based mathematics teaching also focuses on research supporting the most effective teaching strategies for student learning. The National Council of Teachers of Mathematics (NCTM) in the United States, for example, has developed

over several decades very specific standards for mathematics teaching and learning.

[3] Statistical power is a function of sample size. Large samples can detect small, medium, and large effects; small samples can detect only large effects. If we relied on quantitative comparisons alone, our study would be at high risk of Type II error: the failure to recognize the positive outcomes of a program. However, power statistics are estimates: one of the statistical comparisons reported in Table 1 did reach statistical significance. Other educationally meaningful effect sizes shown in the table were not statistically significant; because of the small sample size we are not able to eliminate the possibility that effect sizes arose through chance.

[4] We were unable to render a decision as to the most appropriate level of practice for the three student-student interaction variables in 2 of the 12 cases on the posttest. We treated the data on these variables as missing in the case-wise calculation of the t-tests.

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