MATHEMATICS PROBLEM SOLVING PROFESSIONAL LEARNING THROUGH COLLABORATIVE ACTION RESEARCH

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This paper draws from a study that aimed at finding out how teachers’ collaborative action research in the Teachers Learning Together (TLT) project promotes professional development in the area of mathematics amongst elementary school teachers. The paper focuses on an analysis of teachers’ experiences of teaching and learning of problem solving in a collaborative action research. Qualitative research approach was used to conduct case studies of three teacher-researcher teams. In the two cases analysed in this paper, collaborative action research provided opportunities for teachers to learn about problem solving process, creating an environment that fosters students’ learning through problem solving and mathematics knowledge for teaching

INTRODUCTION

Mathematics education reform movements reflected in documents such as the Ontario Mathematics Curriculum (2005), NCTM Principles and Standards, (2000) call for mathematics teachers and educators to look at different ways of teaching and learning mathematics. One of the elements of these reforms is a focus on problem solving as a key component of effective mathematics teaching and learning. For example, according to the National Council of Teachers of Mathematics (NCTM, 2000), “solving problems is not only a goal of learning mathematics but also a major means of doing so” (p. 52). Recently mathematics education researchers have recognized the importance of mathematics teachers’ understandings of the underlying assumptions and theories of teaching and learning of problem solving as reflected in these documents and their practical applications. As such, researchers have argued for the importance of professional development for teachers to enable them to enact, in their classrooms, the teaching and learning of problem solving.

Traditionally teachers’ professional development models comprised of one-day training workshops provided by experts who come and go. Researchers have argued that this type of professional development does not result in a change of teachers’ practices (Joyce & Showers, 1995). Researchers also contend that professional development that is close to the classroom, collaborative, content focused, and relies on expertise and lived experiences of participating teachers have the potential to affect teaching practices (Kratzer & Teplin, 2007).

This paper draws from a study that aimed at finding out how teachers’ collaborative action research in the Teachers Learning Together (TLT) project promotes professional development in the area of mathematics amongst elementary school
The study was guided by the following questions:

- In what ways does collaborative action research, when used as professional development, influence teaching practice?
- In what ways does participation in teacher-designed action research inform teachers’ understanding of elementary school mathematics and elementary mathematics teaching and learning?

The paper focuses on an analysis of teaching and learning of problem solving in a collaborative action research. TLT is a professional development initiative of The Elementary Teachers Federation of Ontario (ETFO). ETFO invited and provided support for teacher teams from the same school or in similar roles at different schools to come together to conduct action research projects relevant to their specific professional needs, circumstances and interests. For the 2008 school year, the focus of professional development was on mathematics. Over the course of the year, teams of teacher-researchers were supported by university facilitators as they conducted their own research projects at their schools. As part of this project, ETFO contracted university facilitators to facilitate the professional development and conduct three case studies of some of the teacher teams with whom they were working. In this paper we describe some of the findings from two case studies that we conducted -- these teacher teams investigated problem solving in their action research projects.

THEORETICAL FRAMEWORK

The research was framed by the following ideas: teachers develop knowledge of teaching and learning mathematics in practice by engaging in activities that promote collaboration, reflection and experimentation such as collaborative action research; effective mathematics teaching requires a sound knowledge of mathematics for teaching; and teachers need to learn how to teach through problem solving.

Collaborative Action Research

Action research derives its roots from the work of the German social psychologist Kurt Lewin (Carson, 1992). Lewin was concerned about the gap that existed between theories about society and the dynamics of social practice. In the past two decades action research has emerged as a significant form of research into practice. In education, in-service and pre-service teachers are being engaged in action research as part of professional development and as part of educational reform efforts (Feldman, 1996). Following Lewin, various manifestations of action research have developed. Action research can be individual or collaborative. Collaborative action research can be defined as collaborations between teachers and outsiders, such as university researchers (Savoie-Zajc & Descamps-Bednarz, 2007) or collaborations among teachers (Feldman, 1996). In the TLT project, teachers were involved in a collaborative action research. Feldman (1996) defines collaborative action research as research that involves practitioners working together to take actions within their
situations in order to improve their practice and to come to a better understanding of that practice. The words “collaborative”, “research” and “action” in collaborative action research might be conceived as:

- Collaborative: group of teachers working together
- Research: systematic, critical inquiry made public
- Action: Understanding the teaching and learning system requires taking action within the system and paying close attention to the results of taking those actions

In their paper “Complexity Science and Educational Action research: toward a pragmatics of transformation” Davis and Sumara (2005) notice a similarity between sensibilities promoted by collaborative action research and those promoted by complexity science. Both collaborative action research and complexity science are concerned with “what one might do to bring together the self interests of autonomous agents into grander collective possibilities” (p. 454). One way that complexity science addresses this question is by elaborating on conditions that are necessary for bringing together a collective learning system. These conditions include making sure that there is redundancy among the participants in a team. Redundancy, understood as commonalities among participants in a team, is necessary to ensure a transition from a collection of me’s to a collective of us (Davis & Simmt, 2003). Another condition that is necessary for the emergence of a collective learning system involves the presence of diversity among the members of the team. Diversity allows novelty; it is the source of a collective’s flexible response—its intelligence.

**Mathematics Knowledge for Teaching**

The question of the relationship between knowledge of subject matter and knowledge of teaching has been a central concern in teacher education. In practice any mathematics professional development program has to contend with the question of how to integrate knowledge of subject matter (mathematics) and knowledge of teaching. An initial characterization of this integration comes from Shulman’s (1987) work on pedagogical content knowledge. Shulman defined pedagogical content knowledge as a particular form of knowledge that embodies the aspects of content most germane to its teachability. Recently, Ball and Bass (2002) elaborated on pedagogical content knowledge and used the term “mathematics knowledge for teaching” to capture the complex relationship between mathematics content knowledge and teaching. Ball and Bass suggest that any inquiry into teachers’ knowledge of mathematics should begin by analyzing the work of teaching and questioning what mathematics matters for this kind of work; they maintain a delineation between knowing mathematics and knowing mathematics that is useful for teaching. In addition to knowing mathematics content, knowing mathematics that is useful for teaching involves specialized content knowledge that is not pedagogy but includes for example knowing how to represent fractions and decimals with diagrams.
Teaching through Problem Solving

There is consensus in mathematics education about the importance of problem solving and its potential for increasing students’ engagement with mathematics. Consequently, teaching through problem solving has gained prominence in mathematics education over the last two decades. From the student perspective, the experience is one of “learning through problem solving,” and NCTM (2000) states that:

Instructional programs should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; and monitor and reflect on the process of mathematical problem solving. [p. 52]

Although problem solving is regarded as a beneficial approach to teaching mathematics, teachers however, have often found effective teaching of mathematics problem solving to be a major challenge. For example in Finland, Pehkonen (2007) found that teachers who believe problem solving is beneficial still fail to implement it in within their classrooms.

METHODOLOGY

We used qualitative research methodology to conduct case studies of three teacher-researcher teams, focusing on the teachers’ learning as they engaged in their own action research activities. Overall, the two Mathematics educators acted as facilitators for nine teacher-researcher teams as part of the Teachers Learning Together project. ETFO held a symposium over two days in August 2008 where participants were introduced to the Teachers Learning Together project and action research methodology. From the nine teacher teams that were assigned to us by ETFO, we selected three groups to be the focus of our case studies. Selection of teams was based on the following aspects:

- The diversity provided by the three teacher-team projects selected according to their home school districts, the grade levels addressed, mathematic topics addressed, the teachers’ levels of teaching experience, and their experience with research
- The potential of the each team’s plan to address our research questions
- The alignment of the each teacher team’s action research project with the Ontario Elementary Mathematics Curriculum (2005).

Data Collection methods

Data sources were:

1) Copies of teacher-created artefacts relating to the focus of the teachers’ research such as lesson plans, teaching materials, and teachers’ post-lesson reflections in journals: These were collected by the teachers on our behalf throughout the school year
2) Teacher-created action research project reports: The teachers’ final action research reports described and presented findings of how their action research had impacted their professional practice.

3) Transcriptions and field notes of teacher-researcher team meetings (selectively audio-recorded).

4) Our own researcher journals: Each researcher kept a written record of her own reflections relating to the research project over its duration.

5) Transcriptions of one focus group interview per team at the end of the project, audio recorded

DESCRIPTION OF TWO CASES

Case 1: Student Questioning in a Problem Solving Context

This teacher team of four junior division (grade 4-6) teachers were mathematics facilitators from four different schools with a history of engaging in collaborative professional development projects initiated by the Ministry of Education and the District school boards. At the time of the TLT project, the four teachers taught one grade 4/5 class, one grade 5 class and two grade 6 classes respectively, located in two rural and two urban schools. Three schools were K-8 schools and one was a grade 4-8 school. Their research question emerged from observations of students learning during their two-year professional learning in the District School board project that had focussed on teaching through problem solving. Teachers observed that students were not asking mathematically relevant questions and engaging in productive dialogue that furthered their mathematical understandings. They therefore wanted to make math more “visible” to students. For this TLT project, the teachers used instructional strategies that included math congress and gallery walk (Fosnot, 2007; Fosnot & Dolk, 2001; 2002). These instructional strategies involve students in dialogue, conversation, discussion, and questioning of mathematical solutions presented by their peers. After discussions with each other and the researchers, the group narrowed their focus to the role of students’ questioning and dialogue during problem solving contexts. Their research question was: How can we enhance productive questioning and dialogue through the implementation of targeted instruction so that classroom conversations make the mathematics more accessible to all students? The goal of their study was to identify strategies that would promote effective student questioning and dialogue during problem solving to foster mathematical reasoning for all students.

After conducting an extensive literature review, the team observed that most studies on mathematical questioning focused primarily on teacher questioning. The limited literature in the area of student questioning in mathematics meant that the team would have to explore a number of targeted strategies designed to engage students in rich dialogue and effective questioning (by teachers and students), to find out if such
strategies made the mathematics accessible to all students. Since they were already familiar with a number of strategies learned in the district school board project, they decided to try out the following strategies: Math Congress, (Fosnot, 2007), Gallery Walk / Post-it-notes, Think/Pair/Share, Modeling, Anchor Charts, Annotation of Key Mathematical Ideas / Student Comments / Questions, Summarizing / Generalizing, Wait Time / Pacing. Their intent was to try out these strategies, observe students, reflect as a group, and adjust the strategy.

Case 2: Students Communicating their Problem Solving Strategies through Bansho

Participants in this case consisted of four Grade 3 teachers from four different schools and one special assignment teacher in mathematics. Similar to the first team, all five teachers had participated as a group in their school boards’ professional development initiative, prior to the TLT project. The team had been working on problem solving as the focus on the project. They observed that their students had problems communicating their computational strategies during problem solving. Upon further discussion and dialogue with each other and the researchers, they therefore decided to focus on students’ communication of problem solving strategies. Their research question was: “How can we increase our students’ ability to communicate their problem solving strategies more effectively by using the strategy of bansho in the classroom?” They decided to implement bansho, a Japanese strategy where students’ problem solving strategies, serving as a public record, is displayed on a board. The teacher organizes the board writing so that the progression of ideas in the entire lesson builds logically and is captured for the duration of the lesson so that students may use the record for their note taking. The public record, or the bansho, is the class’s collective thinking. The mathematical strand they chose was number sense and operations.

The team initiated the implementation by meeting to familiarize themselves with the mathematical landscape of learning for multiplication (Fosnot, 2007). This was crucial to understanding students’ thinking strategies in problem solving. The teachers selected four different problems that involved multiplication concepts. The implementation was organized in a cycle of co-planning and co-teaching and was repeated 4 times. In each cycle, a bansho lesson was co-planned for half a day, one classroom was selected for two teachers to co-teach the lesson, three other classes were taught by the respective class teachers independently, and all teachers collected student work in the form of the banshos for a post–lesson debriefing on a second half day. During the post lesson debriefing, the team spent time collaboratively dialoguing about their implementation and students’ learning – specifically discussing the bansho strategy and how students’ communicated their learning through the strategy. Based on these post lesson debriefings, they refined how to implement the bansho strategy.
FINDINGS

Through a qualitative analysis of data and informed by theoretical framework we identified a number of themes that characterise the experiences of teachers in collaborative action research. In what follows we present some of the themes which resulted from the analysis of two cases of teachers’ experiences about teaching and learning of problem solving in a collaborative action research.

Relation between collaborative action research and problem solving processes

For the teachers the collaborative nature of the action research process enabled them to experience learning environment similar to an environment that promotes learning through problem solving. In other words as teachers engaged in their own learning, they were empowered to foster the same learning environment for their students. For example one teacher felt that her experience in the project empowered her to be able to create a similar collaborative learning environment in her own classrooms to support students to take ownership and risks in learning.

It really is almost a mirror of exactly what is going on here [action research group]. When you get support, and when you get respect, and when you allow people to sort of figure out and talk to each other and find their way, then you get happier learners. You get more committed learners, you get more enthusiastic learners. You get learners who are willing to take risks, which we all are now. It’s almost like this is the mini version and then we take it back to our classroom and we create it.

Another teacher felt that her own learning process that she was engaged in the TLT action research project reflected the learning process that bansho strategy for teaching problem solving was promoting for her students. Her awareness of her own learning enabled her to support her students’ learning through problem-solving.

I might say the bansho does for the students what the math TLT does for me this year. It validates my opinions, it listens to me, it allows me to show it. The other kind of P.D. we get, is more like the old textbook: “okay, today we’re going to look at pages 1 to 10. Here’s the lesson. I want you to do questions 3 and 4. Take 5 and 6 home for homework. Tomorrow we’ll take it up.” …whereas, the math TLT we’ve been doing this year is a bansho. My opinions are validated. I’m looking at other people’s strategies.

Impact on Students’ Learning through Problem Solving

In a couple of instances, teachers noted that their professional learning in the project had positive effects on their students’ learning. For instance, one teacher expressed how the targeted instruction on developing questioning skills during collaborative problem solving gave students an awareness of the value of learning by listening to different students’ ideas, and engendered respect in students for other students’ ideas.
I think one of the biggest things for me is having the kid that is traditionally smart in math, see a child that he or she would assume is in the lower end of the class, giving a strategy, presenting a strategy, explain their strategy…and then that really sharp kid goes “Ah! I never really thought of it like that!” That opens their eyes to the potential of the other kids in the class, that sometimes they just…ignore...

Teachers in the first case reported progress in students’ mathematical questioning and dialoguing during problem solving. For instance, teachers described students’ growth in mathematical thinking in terms of students’ use of mathematical language in their questioning of peers’ solutions of problems.

As the year progressed we noticed an improvement in the facility with which students used mathematical language. Comments such as: “How did the open array help you?”, “What are the dimensions of the long rectangle?”, “Are those equations part of the Venn diagrams? and “Can it work so that the area stays the same and the perimeter change?” show this development.

**Learning Mathematics Knowledge for Teaching**

It seems that collaborative action research project provided opportunities for teachers to learn mathematics knowledge for teaching. One teacher noted how she was better able to use math resources and know what to look for in the resources in ways that supported her growth in mathematics knowledge for teaching.

My math shelf is constantly [used]…I am constantly taking things off, putting things on, looking things up, making notes, looking for references, figuring out the math, looking at my math dictionary, looking at all my professional resources… and to say, “okay, I want to do this lesson, but what are the strategies that might come out of this problem solving? What might I see on my bansho?” It [action research] certainly, it has been more useful as a professional learning tool than many others.

Teachers identified specific aspects of their projects that had an impact on growth of their knowledge of mathematics for teaching. For example teachers reported how mathematics they focused on in the bansho strategy was also enhanced through reflection on student’s work.

I think we were all aware of it [bansho] before, but having the opportunity to chew it up the way that we did, the depth of our understanding certainly has increased.

By identifying the strategies the students used in our banshos, we also looked for the ways that those strategies were connected with respect to the [mathematics] Big Idea. This enriched our pedagogical content knowledge and sometimes even our own understanding of mathematics.
CONCLUSIONS

In the two cases analysed, collaborative action research engaged teachers in ways that enabled them to learn about problem solving process and how to create an environment that fosters students’ learning through problem solving. Teachers’ participation in the project led to growth of their mathematics knowledge for teaching. Collaborative action research spurred teachers to do their own research into math topics and use a variety of resources to support their planning and teaching. Collaborative analysis of students’ work and teaching strategies promoted reflection on how different problem solving strategies supported growth of student mathematical thinking and increased teacher’s understanding of how to teach through problem solving.

In conclusion it appears that collaborative action research can lead to the generation of new mathematics knowledge and understanding of problem solving for teachers. This has significance for mathematics professional developers and educational reformers. Professional development for teachers should foster a collaborative environment in which teacher can experiment with new ideas in theory and practice.

REFERENCES


