# Numeracy and Beyond: Developing a Mathematical Habit of Mind in K-12

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## Background

The ability to reason with numbers; ask questions of numbers; assess situations and identify problems; recognize the human, interpersonal, technical, scientific and mathematical dimensions of a problem; be creative and innovative in exploring possible solutions; check to see if a solution works; and act on opportunities for improvement are essential dispositions and skills for today's society (Conference Board of Canada, 2003). These fundamental skills that the Conference Board identifies fall under a broad definition sometimes called quantitative literacy or numeracy. "Numerate behaviour is observed when people manage a situation or solve a problem in a real context; it involves responding to information about mathematical ideas that may be represented in a range of ways; it requires the activation of a range of enabling knowledge, behaviours, and processes" (ILSS, p.14).

In July 2003, PIMs sponsored the first part of a two part workshop intended to address the question: what minimum numeracy is required of the average citizen in this computer age? In addressing this question, the committee established as its first priority the need to identify key principles to guide the teaching of school mathematics. These principles should be simple, widely acceptable, practical and yet fundamental. School mathematics enters the discussion of numeracy because it is the primary source of numeracy for most people.

The introduction of numeracy, like the introduction of any new initiative, into the school classroom presents some challenges. In considering how to best go about both formulating and introducing the changes to make numeracy a reality in our schools, it is important to remember that to date most new initiatives have failed to enter the classroom walls (Friesen, 2000; Hiebert, 1997). Eisner (2002) states that there are nine reasons for this failure:

- Internalized images of teachers' roles
- Attachment to familiar pedagogical routine
- Rigid and enduring standards for appropriate behaviour
- Teacher isolation
- Inadequacies of in-service education
- Conservative expectations for the function of schools
- Distance between educational reformers and teachers implementing change
- Artificial barrier between disciplines and between teachers
- Feckless piecemeal efforts at reform

Cuban (2001), speaking of mathematics teaching and learning in the U.S. states that

> high school graduates in 2000 took more mathematics and science courses, did more mathematics and science homework, and read from "better" mathematics and science textbooks than did their forebears. Today's teachers who are certified to teach mathematics and science are familiar with the new mathematics and science curriculum standards that began appearing in the late 1980s. And test scores have improved on national and international standardized tests in mathematics and science, although not to the degree desired.
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> Second, this reform agenda of binding public schools to the nation's economy has led inexorably to producing traditional schools and classrooms that in decorum, subject matter, and teaching style would make the grandparents of today's students feel at home.

> Within this overall climate of heightened concern for preparing students for college and information-based workplaces and increased emphasis on the newest technologies, mathematics and science teachers still lecture, require students to take notes, assign homework from texts, and give multiple-choice tests. If anything, in the past few years mathematics and science classrooms, while awash in graphing calculators and computers, have largely experienced a resurgence of traditional ways of teaching and learning.

What is clear to us is that just increasing the amount of mathematics that is taught will not help us achieve a numerate citizenry. If anything, that seems to have catapulted us backwards. In order for our efforts with numeracy to be realized within K-12, we will need to find different ways to work with teachers to address matters of content knowledge, classroom pedagogy, resources and assessment. We will need to create new ways to engage teachers in professional learning opportunities through which they, themselves, can learn mathematics differently, increase their effectiveness in the teaching of mathematics, engage with and develop more robust mathematical problems, and connect with colleagues and mentors who are also attempting to increase numeracy in their classrooms. The task before us is daunting. What we are attempting to create with numeracy and beyond is a mathematical habit-of-mind (Costa & Kallick, 2001)—a habit-of-mind that develops within citizens the dispositions that the Conference Board of Canada identifies.

**Getting Started: That's A Good Problem**

A small group of mathematicians, math educators and teachers, supported by PIMs, Mt. Royal College and the Galileo Educational Network, have started to address the problem of numeracy in K-12 in Alberta. While we know that there is policy work needed, we have taken a different approach. We have started our work at the classroom. Dr. Jean Springer and Dr. Indy Lagu, mathematicians from Mt. Royal College and Kelly McKie Grenier and I, math educators from the Galileo Educational Network have started an initiative which we call *That's A Good Problem*. This initiative provides teachers, students and parents with an opportunity to engage with mathematics, increases the mathematical understanding and competence of teachers, provides opportunities for deep engagement with mathematics and provides teachers with the opportunity to work with and learn from mathematicians and math educators within the context of their own classrooms.

Schools are invited to send a team of 4 or 5 teachers to a half-day professional development day. The focus of this meeting is on: teaching mathematics through math explorations and investigations by working through a number of math explorations, providing suggestions for introducing math explorations to other teachers in the school and providing suggestions for introducing and organizing a school Math Fair. As teachers work together on math problems, we provide them with the type of mentorship, support and encouragement that we want them to adopt in their own classrooms

Teachers return to their schools with a copy of the *Math Fair* booklet created by Dr. Ted Lewis of the University of Alberta, which contains a number of good math explorations that they introduce to their school staffs and to their students. Jean, Indy, Kelly and I go to each of the schools for a full day to work with teachers and their students as they work on problems from the *Math Fair* booklet and prepare themselves to host a *Math Fair*. This provides teachers with an opportunity to learn in the context of their own classrooms. As a culmination to the work that the students and teachers do, each school hosts a *Math Fair* at which students set up a display of their math problems, but not the solutions to the problems. Students entice their parents and invited guests to work through their math problems. Jean, Indy, Kelly and I attend the *Math Fair* evenings to speak with parents and invited guests about numeracy and mathematics education.

We provide a follow-up half-day professional development session for 4 - 5 teachers from each school. The focus of this session is to assist teachers in learn identify and create good mathematics explorations for their students. We use the following guideline to start working on additional problems for the classroom:

1. Make every exploration begin with a detailed "story".
2. Allow group work, but encourage individual effort.
3. See that students work with mathematical ideas in an active manner.
4. Choose tasks which can be successfully explored at many levels.
5. Design activities which permit innovative solutions by students.
6. Include a rapid evolution from the simple to the profound.
7. Expose the frontiers of knowledge when exploring ideas.
8. Select fun activities which deal with important, useful mathematics.
9. Ensure participation requires the communication of original thought.
10. Provide opportunities for interpretation, multiple correct solutions.

Friesen & Stone (1996)

*Math Fairs* along with the accompanying professional development provide teachers with some definitive guidance on the numeracy needs of tomorrow's students and citizens. Teachers are often surprised at students' ability to engage with the math investigations. Students are often surprised that they have the ability to assist an adult solve their math problem.

> I enjoyed the math fair because it was fun solving the difficult problems. My mom thought they [people] were confused on jumping chips and my mom got frustrated and skipped jumping chips. I felt good because we helped them [parents] instead of them helping us. Math can be fun, exciting and interesting. I would like to have a math fair because we can do better in math and want to do math. We did this because we wanted to see how our parents solve the problems, because they solve them in a more advanced way. – Joel
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> The math fair was a success because we all worked together. I enjoyed making a problem and working in a group. It was hard for my parents to figure out the problem. Helping my parents was good because then it would be easier to make them finish the problem. We should have a Math Fair every year so other people and our parents can learn more math and to give us different ways to do math. It also shows us math is fun and to improve math. Math can be exciting and we can be better problem solvers. – Emmett
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> I feel math is fun again. I went with my uncle and he thought it was really nice. I felt really smart helping my uncle. At first he didn't get it then I told him to read it again. I would want a math fair every year because we can see how smart our parents are. – Sarah
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> I think the Math Fair was fun because I have all the games to myself. I enjoyed when I made the hint cards and made the heads and tails for our game. My mom was confused of my game and when she finished playing she went to Randy's house. When I helped my mom she got better luck of playing. I like the Math Fair because our brain gets smarter and our parents too. Doing different ways to do math is fun. I want to do a Math Fair each year because we will be better at math. Math can be exciting and I can be better at math. – Chi

In addition to creating and finding more engaging mathematical problems and resources to work with, *That's A Good Problem* helped us all, mathematicians, math educators and teachers, to see that what we needed was some way to continue to address matters of curriculum, classroom

pedagogy and the continued development of robust resources in a more deliberate and concentrated way. The *Math Fair* opened the crack to permit teachers and students to see what mathematics learning could be; however, teachers did not have enough mathematical or pedagogical ease to hold the space open or to open it wider on their own. So this year we have added the second component to *That's A Good Problem*—Lesson Study.

**Lesson Study**

> Lesson Study is a professional development process that Japanese teachers engage in to systematically examine their practice, with the goal of becoming more effective. This examination centers on teachers working collaboratively on a small number of "study lessons". Working on these study lessons involves planning, teaching, observing, and critiquing the lessons. To provide focus and direction to this work, the teachers select an overarching goal and related research question that they want to explore. This research question then serves to guide their work on all the study lessons. (Lesson Study Research Group, 2001).

It is our hope that through Lesson Study we will be able to continue to support teachers to continue to address matters of content knowledge, classroom pedagogy, robust classroom and resources. In addition to this expanding the initial work that we began with *That's A Good Problem*, we know that we also need to find ways to help teachers address matters of assessment and integrate numeracy into other subject disciplines.

In life, mathematics is everywhere, and the responsibility for fostering quantitative literacy should be spread broadly across the curriculum. Developing a mathematical habit-of-mind should be regarded as much more than an affair of the mathematics classroom alone. However, for now that has been our starting place because we felt that it was important to get our own house in order first. Our next steps will be to explore the ways in which numeracy can be best achieved through interdisciplinary study.

**Conclusion**

There continues to be much work needed to address the question: what minimum numeracy is required of the average citizen in this computer age? It has been our stance, that while committees meet and policy papers emerge, one of the ways to identify key principles, which are simple, widely acceptable, practical, yet fundamental, which should guide the teaching of school mathematics can be found when mathematicians, math educators and teachers start to work together in the place where all of this agenda will get worked out—the classroom.

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As TIMSS clearly shows, teachers cannot create this place alone. Just writing documents and making teachers more accountable does not help them understand the intent of the new mathematics reforms. Despite the urgency and the pervasiveness of the documents and reform discourse, when teachers look at their own classrooms, they are still left wondering, what do we do differently? What do we reform? All of us who are interested in improving mathematics will have to work this out. We will have to redefine "the basics" so that we can identify the basic attributes of genuinely mathematical thinking, knowing and creating. We will need to create images of practice that best cultivate these attributes, and that speak in compelling ways to the context of North American classrooms. That is, we need to help teachers find answers to yet another question: "what does it look like when teachers and students engage with one another in deeply mathematical ways?"

1. Make every exploration begin with a detailed "story".
2. Allow group work, but encourage individual effort.
3. See that students work with mathematical ideas in an active manner.
4. Choose tasks which can be successfully explored at many levels.
5. Design activities which permit innovative solutions by students.
6. Include a rapid evolution from the simple to the profound.
7. Expose the frontiers of knowledge when exploring ideas.
8. Select fun activities which deal with important, useful mathematics.
9. Ensure participation requires the communication of original thought.

Provide opportunities for interpretation, multiple correct answers.