



**Research Report
Executive Summary**

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Curriculum Implementation in Intermediate Math (CIIM) Executive Summary of Research Report

This executive summary of the Curriculum Implementation in Intermediate Math (CIIM) Research Report provides the background of the research project and a summary of the findings. The full report provides an introduction and five stand-alone chapters on the following topics:

- Transition from elementary to secondary mathematics
- The use of technology in the mathematics classroom
- The use of manipulatives in the mathematics classroom
- Assessment in mathematics
- Professional development in mathematics

This executive summary includes the introduction to the full report so that the context of this research project may be understood. A summary of each of the above chapters is also provided. For more details on any of the topics, the readers are directed to the chapters in the full report.

Introduction

In Fall 2005, the Ontario Ministry of Education introduced a revised curriculum in mathematics for Grades 1–10 that is a refinement of the previous mathematics curriculum introduced in elementary schools in 1997 and in secondary schools in 1999 for Grades 9 and 10. This curriculum encourages inquiry and the development of mathematical reasoning and engages students in mathematical activity to develop an understanding of mathematics concepts as well as mathematical skills. All teachers of intermediate mathematics in the province of Ontario are to implement this curriculum in their classrooms. As with all such important initiatives, those responsible for the initiative as well as those engaged in the initiative itself are interested in knowing how it is working. The Curriculum

Implementation in Intermediate Mathematics (CIIM) research project was initiated in January 2006 to examine how this inquiry-oriented mathematics curriculum for Grades 7-10 in Ontario is implemented and understood by the multiple partners involved. In this report we describe the background, and evolution of this large-scale research initiative and share some of the research findings from the first year of the project.

Background

For a very long time the content of mathematics education has been understood as a set of procedures, rules, and algorithms, and in that tradition the role of the teacher was to introduce these procedures and concepts in a logical sequence, and to provide enough examples and time for learners to practice applying the rules to a set of problems. The current reforms in mathematics education (NCEE, 1983; NCTM, 1989, NCTM 2000) have grown out of a concern over learners' limited understandings of mathematics when taught from this perspective. The mathematics education community increasingly acknowledges that doing and understanding mathematics goes well beyond knowing mathematical facts and procedures. It also means being able to reason mathematically and to have the ability to interpret and solve mathematical problems (Artelt, Baumert, Julius-McElvany, & Peschar, 2003; Ball 2003; Boaler, 2002; Hiebert, 1997; NCTM, 2000). Research shows that children learn more mathematics when instruction is based on students' ways of thinking, when students are engaged in problem solving, (Yackel & Cobb, 1996; Zack & Graves, 2001) and when teachers assist students in seeing the connections among various mathematical ideas (Lampert, 1990). Current mathematics curricula reflect the importance of engaging students in meaningful mathematics content through mathematical activity such as conjecturing, analyzing, investigating, and explaining.

The Ontario math curriculum for intermediate mathematics

The current Ontario math curriculum for intermediate mathematics is aligned with curricula in other jurisdictions and reflects current thinking and research in mathematics education. It has evolved through a collaborative process involving practitioners, policy makers and mathematics education researchers, and the most recent revisions of the curriculum began with the writing of background research reports to inform the curriculum writers of current research. These revisions also included discussions with various stakeholders so that the mathematics education community, as well as other communities, were participants in the curriculum revisions.

Both the current Grades 1 – 8 mathematics curriculum (OME, 2005a) and the Grades 9 and 10 mathematics curriculum (OME, 2005b) present progressive messages about the incorporation of technology, the value of mathematical communication, the importance of deepening mathematical understanding through inquiry and problem solving, and the accessibility of mathematics for all learners. The specific curriculum expectations in the curriculum documents use verbs such as *investigate*, *explain*, and *model*, to encourage a variety of mathematical processes and engage students with meaningful mathematics content. Following is an example of a specific curriculum expectation for Grade 7 that prompts students to recognize relationships between area and perimeter through investigation using a variety of tools such as concrete materials and technology.

Students will determine, through investigation using a variety of tools (e.g., cans and string, dynamic geometry software) and strategies, the relationships for calculating the circumference and the area of a circle, and generalize to develop the formulas. (OME, 2005a, p. 113)

A specific curriculum expectation for Grade 9 directs students to investigate linear relations with the use of technology to determine specific properties (the meaning of slope and y-intercept) of these relations.

Students will identify, through investigation with technology, the geometric significance of m and b in the equation $y = mx + b$. (OME, 2005b, p. 34)

This active investigation of concepts with mathematical thinking tools, as required in the specific expectations described above, allows teachers and students alike the opportunities to engage mathematically as they jointly become aware of patterns, make conjectures, compare results, and provide explanations. This type of engagement creates a space of learning and of opportunity in which different representations often highlight different aspects of a complex concept or relationship which enrich the understanding of mathematical concepts.

Resources and professional development

Recognizing that the new ways of teaching mathematics are challenging for teachers, the implementation of the Ontario mathematics curriculum has been supported in a variety of ways. The Ontario Ministry of Education has provided funding for resources, technology, and professional development to support the curriculum. Resource documents related to intermediate mathematics, Grades 7-10, have been released by the Ontario Ministry of Education through provincial initiatives and include *Think Literacy*, 2003, 2004 and 2005; *Leading Math Success*, 2004; and *Targeted Implementation and Planning Supports (TIPS)*, 2003, 2004 and 2005. The resource that appears most closely connected to teachers' classroom practice is the TIPS document which is a teaching resource that includes detailed course plans, unit plans, lesson plans, blackline masters and reference materials aimed at assisting teachers of Grades 7 and 8, as well as Grades 9 and 10 Applied courses. The TIPS documents also include a 32-page review of research on instructional and assessment practices. There is an online version of the resource that provides tutorials on Ministry-licensed software for the math classroom, and pre-made files for *Geometer's Sketchpad*[®]. In addition there are PowerPoint files for some lessons and videos of planning sessions. To assist teachers in becoming familiar with these materials, the TIPS resource was supported with numerous professional development opportunities.

Other professional experiences and resources have been developed in collaboration with leadership groups in mathematics education such as the Ontario Association for Mathematics Education (OAME) and the Ontario Mathematics Coordinators Association (OMCA). Also, the close collaboration of the Ontario Ministry of Education with OAME and OMCA has helped to develop a strong community in mathematics education, a community that has been able to support mathematics education initiatives.

What this means for teaching

This curriculum challenges teachers with new ways of thinking about mathematics teaching and learning. While the implementation of a reform mathematics approach requires the alignment of several components including curriculum, resources, activities, classroom structures, teaching approaches, and the role of the teacher, the research suggests that the actual practice of teaching, such as the way a teacher poses questions or responds to students' understandings, is the most critical element (Ball & Bass, 2002; Boaler, 2002). In our view the kinds of changes teachers are asked to undertake in order to successfully engage all learners in mathematical inquiry, are not simple and require a substantive re-orientation of their basic beliefs about mathematical ideas as well as mathematics teaching and learning. Even when curricula are available and are supported by professional development and resources, reform-oriented teaching practices are not necessarily evident (Ball, 2003; Frykholm, 1999). The posing of problems, the facilitation of discussion, and the consolidation of mathematical concepts are teacher practices that require a great deal of knowledge and attention. In many cases, teachers, themselves, have not learned mathematics in this way, nor have they had opportunities to learn and teach in inquiry-oriented settings. We know that even when teachers have had some inquiry-oriented learning experiences and acknowledge this approach as supporting their understanding of mathematics, there remains a visible tension between the reform-

oriented and traditional approaches to teaching mathematics (Jacobs, Hiebert, Givven, Hollingsworth, Garnier, & Wearne, 2006).

The CIIM research project

The Curriculum Implementation in Intermediate Mathematics (CIIM) research project was initiated in January 2006 to examine how this inquiry-oriented mathematics curriculum for Grades 7-10 in Ontario is implemented and understood by the multiple partners involved. Our goal was to design and carry out a research project that strengthens our connections between researchers, teachers and policymakers in order to understand the complex process of implementation of inquiry-oriented mathematics curricula. It is important for us to conduct research that is useful to practitioners and policymakers so that they can make more informed decisions. From our perspective, however, it is not only a matter of bringing research into practice and policy, but of understanding policy and practice as we do research. Therefore our research design is multi-faceted and longitudinal as we work to understand how the new curricular and pedagogical experiences are understood by policy makers, mathematics educators, and researchers.

The research team

Our University of Ottawa research team is comprised of two university researchers, a project manager, and graduate student research assistants. The team has a variety of expertise and experience in curriculum, instruction and assessment, and teacher development. Several of the graduate students are or have been teachers in the Ontario system and therefore have first-hand experience of the curriculum and are aware of many of the math initiatives in Ontario. We are also working in collaboration with Dr. Geoffrey Roulet from Queen's University and several of his graduate students as research assistants.

Research design

This research project is designed to address the following aspects of the curriculum implementation:

- To determine how the current intermediate mathematics curriculum is understood and taught
- To understand how teachers have been supported in the implementation of this curriculum
- To describe learning environments that reflect the enactment of the curriculum

These research issues are addressed through a longitudinal, multi-faceted research design that includes focus group interviews, a web-based questionnaire, and case studies. Below is a list of the design components, followed by fuller descriptions of each.

- Focus groups interviews with leaders in mathematics education (Winter 2006)
- Web-based questionnaire for math teachers in grades 7 - 10 (May to mid-July 2006)
- Case studies in classrooms that have been identified as implementing the curriculum (2007-2008)
 - Focus group interviews with teachers (Spring/Fall 2007)
 - Classroom site data collection (2007-08)

In this report we are presenting results from the focus group interviews with math education leaders and the web-based questionnaire for math teachers Grades 7-10.

Interviews with math education leaders in Ontario

Focus group interviews with mathematics coordinators, and leaders in mathematics education provide an important contribution to our understanding of the multiple perspectives of the curriculum and its implementation. These participants have been actively engaged in the curriculum implementation process and have worked extensively with teachers, administrators, and other leaders in the mathematics education community. It was important for us to listen to their expertise and

experience to begin to understand the types of implementation supports that teachers have received, the level of curriculum implementation to date, and the professional development that they feel is still required. To recruit participants for this phase of the research we contacted the presidents of two professional associations, the Ontario Association for Mathematics Education (OAME) and the Ontario Mathematics Coordinators Association (OMCA) to inform them of the project and to request permission to address members of their respective organizations. Once they gave us permission we provided them with a recruitment email letter to distribute to the OMCA members and the OAME directors. The letter invited leaders in mathematics education to share their expertise and experience in focus group interviews or individual interviews to be scheduled at an upcoming meeting of their association. We informed them that all individual and focus group interviews would be audio taped. We suggested a number of possible meeting times and requested that those who were interested reply to us by email.

In February 2006 we conducted interviews with math education leaders who were attending the Board of Directors meeting of the Ontario Association for Mathematics Education (OAME). We held 3 focus group interviews with a total of 8 participants. We also attended the February meeting of the Ontario Mathematics Coordinators Association (OMCA) meeting in Waterloo, Ontario to present our research project and to conduct focus group interviews. At this meeting the participant groups were created through “open-space technology”, a strategy that allows participants to suggest relevant topics and to negotiate these topics to form discussion groups. Based on the interests of those present, three topic groups emerged. These were assessment, teachers’ use of tools and strategies to teach math, and the role of mathematical processes. Over 20 OMCA members participated in these 3 discussion groups. The discussions within these groups were not limited to the original topic. In fact, in all of our discussions with math education leaders our data suggest that topics were wide ranging and covered

many aspects of curriculum implementation. All focus group interviews were audio taped and transcribed.

Our 6 focus group interviews revealed that the leaders in math education have a good understanding of the curriculum and are knowledgeable about current teacher practice including how the curriculum is enacted by teachers in their communities. They seemed to be in touch with the state of implementation, the successes to date and the work still to be done. A preliminary analysis of the data from these focus group interviews identify some recurring themes that helped inform the design of the teacher questionnaire.

Web-based Teacher Questionnaire

Another component of this research was a web-based questionnaire for teachers of Grades 7-10 mathematics that was made available online from May to mid-July 2006.

Questionnaire development. In designing the questionnaire, we examined a variety of other questionnaires that had been developed for teachers including those from TIMSS, PISA, and EQAO. We also consulted members of the Ontario Ministry of Education Advisory Panel for Connecting Practice and Research in Mathematics Education. Once the questionnaire was designed, members of the Advisory panel as well as researchers in other universities were consulted for feedback. A paper version of the revised questionnaire was then pre-tested by practicing teachers. The pre-testing led to further revisions and also helped to determine the amount of time needed for participants to complete the questionnaire. A web-design team then transformed the paper format into a web-based questionnaire. They then tested the web-based version extensively to ensure that it would perform in accordance with our specifications once it was online.

The content of the items included teaching experience, background in mathematics, understanding of the curriculum, instruction and assessment, and professional development. More specific topics were:

- What are the current practices of teachers of mathematics?
- What types of instructional activities are students engaged in?
- What forms of assessment are being used in mathematics?
- How do teachers use assessment data?
- What are teachers' understandings of the curriculum?
- How well do these current practices match the new curriculum?
- What are the supports that teachers have received for curriculum implementation?
- What are some of the challenges that teachers face in implementing the curriculum?
- What types of support are needed to enhance curriculum implementation?

The final questionnaire had a total of 45 items some of which were general questions while others were course specific. For course-specific items, we asked respondents to identify one particular math class that they were teaching during the school year and then use that class as the basis for their answers. The course-specific items allowed us to distinguish different practices, activities and attitudes associated with different courses. Following is an example of a general question and course-specific question.

Example of a general question

To what extent do you think your philosophy of teaching/learning mathematics is aligned with the philosophy of each of the following? Check one box in each row

	Not applicable	Not at all	A little	Somewhat	A lot
a) Your colleagues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b) Your mathematics consultant/coordinator	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c) Your department head	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d) Your principal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
e) The Ontario mathematics curriculum	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Example of a course-specific question

In **this class**, how important is each of the following? Check one box in each row.

	Not at all	A little	Somewhat	A lot
a) Providing students with many examples	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b) Encouraging student discussion of mathematical ideas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c) Promoting the use of multiple representations of ideas (concrete materials, technology, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d) Providing opportunities for students to explain their reasoning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
e) Providing engaging problems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
f) Providing students with opportunities to practice skills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Distribution of web-based questionnaire. One of the challenges of this research was how to identify and contact the teachers in the province who are teaching intermediate mathematics. When we began, we assumed that someone would have this information, but as we inquired we soon came to realize that it is not clear exactly who is teaching intermediate mathematics. Therefore we needed a strategy for contacting those teachers, and we developed the following approach. We sent letters to Directors of every English school board in the province inviting their board to participate in the web-based teacher questionnaire. If they accepted our invitation, the boards provided us with a contact

person who could tell us the number of schools in their board where intermediate mathematics was taught. With that information, we designed a package for each school consisting of ten letters addressed to intermediate math teachers in the school and one letter for the school principal. In schools with large math departments we sent additional letters for teachers. The letters for the math teachers described the project and invited them to participate. Each letter included an individual access code and information about how to access the online questionnaire. The board contact persons distributed these packages to the schools in their boards. Out of 60 boards contacted, 42 accepted the invitation. In total, 1096 teachers responded to the questionnaire with a representative distribution of school boards and grades.

Who were the respondents? The sample was nearly evenly divided with 46% teaching Grades 7 and 8, and 51% teaching Grades 9 and 10. Only 3% of respondents reported “other” as their teaching assignment. The majority of respondents (93%) identified their primary role as a full time classroom teacher. Of the teachers of Grades 7 and 8, 42% reported that they teach math for 60 minutes or less each day while 31% report teaching math for more than 60 but less than 90 minutes daily. This suggests that these Grade 7 and 8 teachers were responsible for the full range of subjects in the Grade 7 and 8 classes, rather than focusing on one subject on a rotary timetable. Of the teachers of Grades 9 and 10, 62% report that they teach math 3.5 hours or more daily. This suggests that more than half of the teachers of Grades 9 and 10 in the survey teach a full timetable of math.

Table 1: The questionnaire respondents

	Frequency	Percent of respondents
Grade 7 and 8 teachers	506	46%
Grade 9 and 10 teachers	559	51%
Other	31	3%

Case Studies

In addition to the questionnaire and interview data, our research includes a number of case studies to obtain specific details about the curriculum implementation in classrooms and schools. These case studies focus on learning environments that reflect the enactment of the curriculum.

Focus group interviews with teachers (2006-2007). In preparation for the case studies we held with focus group interviews with selected teachers in various regions in the province, beginning with Eastern Ontario. These teacher focus group interviews provide us with information about specific classroom practices in intermediate mathematics and also provide an opportunity for developing a relationship with the teachers as collaborative partners.

Classroom sites. The case studies of classrooms are being conducted in various school boards across Ontario. The data from the case studies include audiotaped interviews with teachers and principals, videotaped classroom observations of 5-7 mathematics lessons, collection of documents such as instructional and assessment activities, and board and school policies that affect classroom practice. The analysis of the case study data will help us to describe and understand the implementation of the curriculum in various contexts.

Transition from Grade 8 to Grade 9 Mathematics

The research literature on students who are making the transition from elementary to secondary school directs our attention to the complexity involved in transition and cautions that the inability to adjust can have an adverse effect on success in completing high school. The Ontario mathematics curriculum documents recognize that there should be a smooth transition from elementary to secondary school.

The Grade 9 courses in the Ontario mathematics curriculum build on the knowledge of concepts and skills that students are expected to have by the end of Grade 8 the mathematics courses offered in secondary school are based on principles that are consistent with those that underpin the elementary program, a feature that is essential in facilitating transition (OME 2005a, p. 4).

Our data suggest that many teachers may not be fully aware of the content and expectations of the mathematics curriculum of the other panel and may benefit from opportunities to explore the curricula of other grades. In order to understand how familiar teachers in each of the different panels were with the curriculum expectations for different grades we asked the following in the teacher questionnaire:

How familiar are you with the current Ontario curriculum expectations for each of the following courses?

While the question was developed for all courses and all grade levels, Table 2 shows how teachers of Grades 7 and 8 and teachers of Grades 9 and 10 characterize their familiarity of the curriculum expectations for Grade 8 and Grade 9 Academic Mathematics, respectively.

Table 2: Familiarity with mathematics curriculum expectations for Grade 8 and Grade 9 Academic Mathematics.

Familiarity	Grade 8 Mathematics		Grade 9 Academic Mathematics	
	Grade 7 and 8 teachers	Grade 9 and 10 teachers	Grade 7 and 8 teachers	Grade 9 and 10 teachers
Not at all	3%	20%	24%	2%
A little	5%	36%	33%	5%
Somewhat	18%	36%	35%	18%
Very	75%	8%	8%	76%

While 75% of the teachers of Grades 7 and 8 are *very* familiar with the curriculum expectations for Grade 8 mathematics, only 8% report being *very* familiar with the curriculum expectations for Grade 9 mathematics. The situation is reversed when we look at the Grade 9 and 10 teachers’ familiarity with the curriculum expectations for those two courses. In that case, 76% of the Grade 9 and 10 teachers report being *very* familiar with the curriculum expectations for Grade 9 mathematics, while only 8% report being *very* familiar with the Grade 8 curriculum expectations.

In addition, our findings reveal that there are several differences between the teaching and learning cultures in Grades 7 and 8 and in Grades 9 and 10, a conclusion that is also found in the research literature. This then underscores the need for increased dialogue in order to address these issues, and to develop an awareness and understanding of both the curriculum and the cultures of schooling as experienced in the different panels. In fact, with respect to transition, both the research literature and many of the results from this study point to the importance of establishing the practice of collaborative communication among teachers from both panels.

Given the importance of dialogue between the panels, it is valuable to learn about the opportunities for communication between the two panels. Of particular interest was the frequency of

meetings between teachers from both panels to discuss issues pertaining to transition. The question we posed is as follows:

Teachers of mathematics in Grades 7, 8, 9, and 10 may meet together to help ease the transition of their students from Grade 8 to Grade 9 mathematics. During the current school year, how often will you have met with your colleagues in the other panel?

In response to this question, 46% of the teachers reported that they had not met with their colleagues at all. Table 3 shows the distribution of meetings.

Table 3: Meeting with colleagues to discuss transition

Frequency of meeting	Percentage
Have not met	46%
Once	25%
Twice	14%
Three times	7%
More than three times	7%

The data would suggest that more opportunities for discussions across the panels are needed. There are many possible topics of conversation that would be of value for teachers including specific classroom practices, as well as engaging with each others' perceptions of what is required to be a good mathematics student and how that appears different depending on the grade level and specific course focus. These conversations can occur naturally within shared activities and in fact, there is evidence that such conversations might be more effective when they occur in the context of collaborative work. "It isn't just talk but work that binds" (Hargreaves & Earl, 1991, p.70). In our data, the effectiveness of such a shared activity was described in relation to a professional development initiative on how to use TIPS documents. As one mathematics leader stated, TIPS was effective because it "moved people along . . . it opened a dialogue between 7, 8 and 9 teachers . . .

was organized so that they were together and . . . they were all learning at the same time (Joan, Math Leader Focus Group [MLFG] 2).

The Use of Technology in Mathematics Class

A number of observations and connections can be made from the various sources of CIIM data with respect to the use of technology in mathematics classes. One is the observation that the positioning of technology within the curriculum is very much aligned with the current thinking expressed in the research literature. Other observations include the recognition from the questionnaire data that a fair number of teachers are using technology in the teaching of mathematics, that access to computers is an issue in the use of technology, and that teachers are suggesting that they would like more professional development in the use of technology as well as time to explore the technology that they would use to teach mathematics.

Use of technology

Approximately 90% of teachers in the Grades 9 and 10 Applied and Academic courses report that their students use graphing calculators in at least some of the lessons. These data suggest that these teachers perceive themselves as comfortable with the technology and are making it readily available for student use. This wide use of graphing calculators is also echoed by the mathematics education leaders in the focus group interviews. These focus group data also highlight the importance of continued support for the use of graphing technology and the role that the collaboration of peers has played to support this use.

Also, nearly half of the teachers across Grades 7-10 report that students in their classes use dynamic geometry software (specifically, The Geometer's Sketchpad[®] [GSP]) during at least some lessons. While this provides evidence of many teachers using dynamic geometry software, it also

prompts us to seek ways to help more teachers provide opportunities to their students to investigate mathematical ideas with dynamic geometry software, as the use of dynamic geometry software is prevalent in the intermediate math curriculum. Professional development and collegial support may provide opportunities for teachers to work with GSP, as over one third of teachers who offered comments about technology in the open-ended question regarding professional development reported positive influences on the value of GSP workshops. Also, we see support for GSP within the TIPS resources as they include many pre-made sketches included as part of complete lesson plans for use by teachers. The availability of pre-made sketches and applets was identified by mathematics education leaders as assisting teachers in overcoming fear of using dynamic graphing software.

Access to computers

While there is an increased emphasis on technology in the curriculum, only 1 out of 4 teachers report *Often* or *Always* being able to use the computer lab when they need it. The issue of access to computers is reflected in both the interviews with math education leaders and teacher questionnaire responses. The research literature also points to the challenge that teachers face with easy and timely access to technology, whether in computer labs or within the classroom and suggests that teachers with access to a healthy, encouraging, and technology-competent human infrastructure, and a functional, convenient, and easy to access technical infrastructure, are more likely to develop positive attitudes towards, and effectively integrate technology into their practice (Forgasz, 2006; Zhao & Frank, 2003).

The role of professional development

While many teachers are using various technologies in their classrooms, there is still more work to be done. Teachers' lack of comfort with technology as well as their lack of knowledge about the technology and its appropriate use in teaching mathematics are cited in the research literature as barriers to implementing technology effectively. The focus group data from the leaders in

mathematics education and the teacher questionnaire data suggest similar challenges. As the focus group participants noted, some teachers are anxious as they are asked to move out of their comfort zone and integrate technology in the teaching of mathematics.

However, both questionnaire and interview data from the leaders in math education suggest that teachers recognize the importance of ongoing professional development in developing expertise in using technology. This is supported by the research literature that shows that professional development helps to prepare teachers to use technology in their classroom and integrate it more effectively into their learning plan. Teachers responding to the questionnaire also mention the importance of having time to ‘play’ with the technology to increase their own competence and comfort level. In addition to formal professional development, participants in the math education leader focus groups and questionnaire responses support the research literature in acknowledging the importance of teacher support and opportunities for collaborative learning that comes from interactions with other mathematics teachers, and especially those peers who have been able to integrate technology effectively.

The Use of Manipulatives in Mathematics Class

The research literature on the use of manipulatives in mathematics teaching and learning directs our attention both to the educational value of manipulatives as well as to the complexity involved in using them effectively. The role of the teacher in the appropriate use of manipulatives in developing mathematical understanding is critical.

Physical apparatus does not offer unmediated mathematical experience in itself, it can neither contain nor generate mathematics. Only people can do this, with their minds, and it is a central part of a teacher’s role as teacher to help pupils to become able to do this for themselves. (Pimm, 1995, p. 13)

The Ontario curriculum documents acknowledge the important affordances of manipulatives that allow learners to move within and between multiple representations of mathematical concepts and constructs in order to develop their mathematical understanding. In the curriculum documents, manipulatives are given equal weight to other representations (numeric, geometric, graphical, algebraic and pictorial) and are described as “necessary tools for supporting the effective learning of mathematics by all students” (OME, 2005a & 2005b, p. 23).

The data from the questionnaire and focus group discussion with math education leaders suggest that not all teachers see value in the use of manipulatives for all of their students. As one mathematics education leader explains:

Sure. The other thing is I don't think they [teachers] realize that mathematicians use manipulatives, use all kinds . . . even in post-graduate work, there are things used to help people to understand mathematics and if we could sort of impress upon them that it's a useful tool, and it might help them even to understand the math, then I think we'll see more of it with their students, but I think we have a way to go. (Joan, Mathematics Leader Focus Group [MLFG] 2)

The questionnaire data suggest that teachers view the use of manipulatives as more appropriate for students in Grades 7 and 8 and the Applied and Locally Developed courses in Grades 9 and 10. The math education leaders stated that many teachers, primarily those at the secondary level, believe that manipulatives are only necessary for assisting struggling learners as they help students move from the concrete to the abstract. They also reported that teachers who work with students in higher grades view manipulatives more as toys that real mathematicians wouldn't use.

These results are echoed in the research literature that report that manipulative use is often valued more for instructing younger students and that their use declines in later grades, even though evidence is provided that manipulatives help all learners. Several studies that examined the cause of declining

manipulatives use in later years (Gilbert & Bush, 1988; Perry & Howard, 1997) suggest that one reason for this appears to be lack of teacher knowledge in the use of manipulatives as well as a lack of understanding of the mathematics connected to the manipulative. This issue is also mentioned by the math education leaders who suggested that teachers may be intimidated by the mathematical possibilities raised by using manipulatives, as manipulatives move teachers outside the comfort zone established when using more familiar algorithms and methods.

The data from the questionnaire, however, show that 67% of respondents considered that additional professional development related to the use of concrete materials and manipulatives would be of value. The math education leaders reported that when teachers were presented with professional development opportunities to learn about and experience using manipulatives, they became more open to using them in their classrooms. These findings are supported by the research as well.

Designing professional development that provides teachers with deeper understandings of concepts such as representation and its role in mathematics teaching and learning may shape not only how the manipulatives are used but also what beliefs motivate teachers to use them (Moyer, 2001, p. 194)

The math education leaders reported that professional development that was sustained over time seemed to work better than short term initiatives and was greatly appreciated by teachers. Participation in a community of teachers working together with manipulatives to teach math was seen as a very effective approach to support teachers. Such initiatives allowed teachers to personally deepen their mathematical understanding as well as see how working with manipulatives could do the same for their students. This was the case when teachers worked with other teachers within the same grade, and when they worked with colleagues from across the grades.

Assessment

A number of connections can be made between the various sources of CIIM data with respect to assessment as well as to the issues described in the research literature. One of the dominant messages in the research literature and in the NCTM assessment standards (1995) with regard to effective mathematics assessment is the need for teachers to use a variety of assessment methods. This message is also a central element in the Ontario curriculum documents. Using a variety of assessment methods helps to ensure that all students have an opportunity to demonstrate their learning as well as avoiding a reliance on only paper-and-pencil tasks such as tests and quizzes which tend to emphasize merely knowledge recall and procedural learning (Shepard, 2001). The use of a variety of forms of assessment that both elicit and contribute to developing mathematical understanding and the full range of mathematical processes is critical in mathematics classrooms.

Observations from the CIIM research project suggest that while quizzes and tests are still the most frequently used form of assessment both in getting a sense of students' understanding and in determining students' marks, some teachers are also using other forms of assessment such as performance tasks, observations, and student responses in class. Comments made in the mathematics leader focus groups and in response to the open-ended items on the questionnaire also confirm this as they suggest that while teachers are moving toward using more assessment forms, there is still a strong reliance on tests and quizzes. Some reasons for this are suggested including a lack of time available to develop new forms of assessment, the need for more professional development with regard to newer forms of assessment, teachers' views of mathematics and mathematics teaching and learning, and mixed messages and inconsistent support for new practices.

As well, the types of assessments that the teachers are using to get a sense of students' understanding might indicate that further work needs to be done in the use of formative assessment. These observations are consistent with the findings of other research studies (Barnes, Clarke & Stephens, 2000; Manouchehri, 1998; Tierney, 2006; Wiliam, Lee, Harrison, & Black, 2004).

Some of the other challenges in expanding teachers' assessment practice that are identified in the research literature are reflected in the observations we have made. Data from the math education leader interviews and questionnaire responses from teachers suggest that some teachers find new assessment ideas challenging and difficult to understand. For instance, teachers report being uncomfortable with the use of the Achievement Chart and struggle with separating assessment tasks into discrete processes or categories. This is understandable as the mathematical processes are interconnected and are not easily separable. For the elementary teachers, the intent of the requirement to report by content strands is not clear. This seems to result in teachers conforming to mandated policies without necessarily understanding the rationale for the policy.

In general, our observations indicate that teachers' use of a range of assessment practices is emerging. Our data as well as our review of the research literature suggest that teachers can be further supported through leadership, collaborative work with colleagues, and transparent alignment of curriculum, instructional, and assessment documents and policies (Barnes, Clarke, & Stephens, 2000; Manouchehri, 1998; Wiliam et. al., 2004). It is also important to recognize that change takes time. Developing new assessment strategies is closely aligned with developing new classroom instructional practices. Some would suggest that as teachers continue to develop their expertise in engaging students in mathematical investigations, providing problem solving activities, and offering opportunities for students to develop conceptual understanding of mathematics along with the application of procedures, they will recognize the value of using a variety of types of assessments to

capture student understanding (Graue & Smith, 1996; Suurtamm, 2004).

Professional Development

A number of observations and connections can be made from the various sources of CIIM data with respect to professional development. The data from the leaders in mathematics education reflects the evidence presented in the research literature that suggests that engaging teachers in new ways of teaching mathematics is a challenge. However, leaders in mathematics education as well as many teachers responding to the web-based questionnaire are able to describe particularly effective professional development opportunities that have helped make positive changes to their classroom practice. Many of these professional development opportunities have addressed teachers' understanding of mathematics or how students learn mathematics, as well as developing confidence in teaching mathematics.

Teachers' responses to the questionnaire also suggest that there is a desire for further professional development in areas connected to new ways of teaching mathematics. The following table identifies the percentage of teachers in each panel who feel that further professional development in particular areas would *somewhat* or to *a great extent* help support their implementation of the curriculum.

Table 4: Areas of further professional development seen as helpful for the category *somewhat/a lot*

Areas for professional development	Somewhat/A lot		
	Grade 7 and 8 teachers	Grade 9 and 10 teachers	All respondents
Teaching through problem solving	84%	75%	78%
Understanding how students learn mathematics	78%	67%	72%
Teaching strategies	76%	66%	71%
Use of manipulatives	79%	57%	67%
Assessment in mathematics	79%	55%	66%
Using group work in mathematics	71%	52%	61%
Facilitating investigations	67%	54%	60%
Use of other computer software (other than GSP)	72%	42%	56%
Use of Geometer's Sketchpad	68%	40%	53%
Use of graphing calculators	52%	42%	46%
Content knowledge for teaching	48%	27%	37%
Other (please specify in comments section on the next page)	30%	24%	27%

The CIIM data also suggest that teachers have engaged in a variety of professional development models that include workshops, lesson study, leadership opportunities and visiting colleague’s classrooms. However, there are specific characteristics of professional development that emerge as very important in supporting changes in classroom practice. One pertains to the importance of dialogue with colleagues and opportunities for collegial collaboration. Through informal collaboration in regular meetings with other teachers in one’s school, or through collaboration occurring in other settings such as lesson study or resource development, teachers and math education leaders reported that they learned much from their peers and valued the opportunity to do so. Since dialogue with colleagues appeared as a useful support for curriculum implementation, it is valuable to look at one of the items in the questionnaire that specifically addresses opportunities for teacher collaboration. Teachers were asked:

How often do you meet with other teachers to discuss and plan mathematics curriculum or teaching approaches for mathematics?

Table 5 presents the summary of responses by panel as well as for all respondents as well as the responses by panel.

Table 5: The regularity with which teachers meet to discuss and plan mathematics curriculum or teaching approaches.

	Grade 7 and 8 teachers	Grade 9 and 10 teachers	All respondents
Never	6%	1%	4%
Once or twice a year	32%	13%	23%
Every other month	16%	8%	11%
Once a month	24%	18%	20%
Once a week	13%	20%	17%
Two or three times a week	6%	20%	14%
Almost every day	4%	19%	12%

The table shows that 43% of all respondents report meeting at least once a week. When the data are organized by panel, 59% of the teachers of Grades 9 and 10 report meeting at least once a week compared with 23% of teachers of Grades 7 and 8. In addition, 38% of teachers of Grades 7 and 8 compared with 14% of teachers of Grades 9 and 10 identified meeting only once or twice throughout the year or not at all.

Another characteristic that emerged was the effectiveness of those professional development initiatives that were connected to classroom practice and sustained over time. The participants reported that opportunities to engage in new ideas with colleagues, try them out in classrooms, and re-visit them in further discussions was responsible for renewed energy and insight. These findings are in keeping with the research literature in which peer interactions among teachers, sustained over time,

have a positive impact on their understanding of mathematics and their teaching practices (Crockett, 2002; Manoucherhi, 2002). The kinds of changes teachers are being asked to undertake to promote deeper mathematical understanding are complex and require a substantive re-orientation of their basic beliefs about the world in general, and mathematics education in particular. Such a re-orientation requires time and ongoing and iterative cycles of professional and classroom engagement (Adey, 2004; Borasi, Fonzi, Smith & Rose, 1999; Garet, Porter, Desimone, Birman, & Yoon, 2001; Loucks-Horsley, Hewson, Love & Stiles, 1998).

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