Bridging the literacy – mathematics divide: Ontario secondary school mathematics teachers’ views and strategies for integrating literacy and mathematics in their instruction and assessment of grade nine to twelve mathematics courses.

By

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ABSTRACT

Mathematics is commonly viewed as a discipline of numbers and symbols by students, parents and some teachers. Little attention is paid to the intricate interplay of language and literacy in mathematics. Despite this, the Ontario Ministry of Education expects that all teachers are teachers of literacy. Accordingly, this study examines how Ontario secondary school mathematics teachers view and integrate literacy and mathematics into their instruction and assessment of secondary (grades nine to twelve) mathematics courses, as well as, the challenges they face in doing so. Using qualitative methods, semi-structured interviews were conducted with six experienced high school mathematics teachers from schools in the Greater Toronto Area. Findings explore teachers’ views of literacy as functional communication tool; instructional methods for teaching literacy in the context of mathematics; the role of literacy in assessment as, for and of learning of mathematics; accommodations for English Language Learners and students with a language-based Individualized Education Plan; and finally, challenges in integrating literacy and mathematics. These findings are reported and discussed with connections to relevant literature.
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Chapter 1: INTRODUCTION

1.1 Introduction to the Research Study

Literacy is an integral part of everyday life in a North American society. News reports on TV, billboard advertisements, newspaper articles, web pages, bus schedules – these are all familiar forms of communication that we frequently interact with. What we do not often think about, however, is the literacy required to interpret the information presented in these forms. “Those who use literacy take it for granted – but those who cannot use it are excluded from much communication in today’s world” (UNESCO). With new technologies and new ways of communicating establishing themselves in the twenty first century global landscape, literacy is a basic requirement for participation in society.

With the increasing importance of literacy, the bar is raised higher for schools to equip students with literacy abilities at a level that allows full functioning in society. The Ministry of Education in Ontario recently came out with a number of documents on this issue. Think Literacy Success Grades 7-12 (2003a) is a report of an Expert Panel on Ontario Students at Risk in the area of literacy. The document clearly states that it is the responsibility of all educators to ensure that students graduate with the necessary literacy “skills” (English-language Expert Panel on Students at Risk, 2003). The panel also points out that “recent provincial testing results have shown that too many students are not achieving the level of success in literacy that will allow them to participate fully in Ontario society” (English-language Expert Panel on Students at Risk, 2003, p.12).
Literacy also has a huge impact on success in all subject areas and school in general. Rowe and Rowe (2000) find that the most important factor influencing student learning, attitudes and behavior is effective teaching focused on literacy, verbal reasoning and written communication skills. Literacy is required for learning in all disciplines: mathematics, science, history, etc. Furthermore, adolescents require explicit instruction in literacy throughout their high school years. For example, Manuel (2003) concludes that learning to read is an ongoing cognitive need for all adolescents.

Current academic research and Ontario Ministry of Education policy highlight the need to teach literacy to high school students and place this responsibility on all secondary school teachers. It is no longer sufficient to rely on English departments to teach literacy. Literacy instruction should happen in all subjects, including mathematics. However, my recent experience as a teacher candidate and past volunteering encounters with literacy and mathematics indicate that a gap exists between Ministry of Education expectations and current teaching practices in high schools of the Greater Toronto Area.

The Ontario Ministry of Education policy states that all teachers are teachers of literacy. Current mathematics teacher practices do not reflect this expectation. Thus, there is an urgent need for more research in the area of literacy and mathematical content instruction and assessment in secondary school mathematics classrooms. What might literacy and content integrated teaching look like in a secondary school mathematics classroom?

1.2 Purpose of the Study

The purpose of this study is to advance knowledge regarding content and literacy integrated teaching in a regular secondary school mathematics classroom. Current research does not address this issue in depth. Particular focus is placed on teaching methods and assessment as
practiced by mathematics teachers in regular urban high schools. An exploration of teachers’
diverse experiences with literacy can also highlight the challenges of teaching literacy in a
mathematics classroom.

The project aims to serve teachers and students’ needs by connecting literacy and
mathematics instruction and assessment. High school mathematics teachers should be equipped
with the necessary skills, strategies and practical ways of teaching and assessing literacy in their
classrooms. Common and recurring challenges and problems also need to be addressed with
enduring solutions. This will allow mathematics teachers to better meet the expectations of the
Ontario Ministry of Education regarding literacy and to contribute to student success.

This research study is also connected to issues of equity in high school classrooms. Jim
Cummins (2010) notes that “it is no longer sufficient to be an excellent science teacher or math
teacher in a generic sense; excellence must be defined by how well a teacher can teach science or
math to the students who may be in the early or intermediate stages of English language
acquisition” (p.7). Mathematics teachers should be aware of the linguistic and multicultural
diversity of students in their classrooms and tailor their teaching according to all students’ needs.
Content and literacy integrated teaching may increase access to mathematical knowledge. It can
also help students to prepare and perform better in graded evaluations. By raising an awareness
of the relationship between literacy and mathematics among policy developers, teachers, and
researchers more effective teaching approaches can be developed to ensure that all students have
access to mathematical knowledge and learning in secondary school mathematics classrooms.

1.3 Research Topic/Questions

The overall goal of this project is to investigate underlying issues in literacy and
mathematics at the secondary school level (grades nine to twelve) with a particular focus on
integrated instructional methods, literacy in assessment and challenges experienced by mathematics teachers. Several sub-questions help to guide the research within the broader topic:

- What are the practical ways of teaching literacy in grade nine to twelve mathematics classes in adherence with the Ontario Ministry of Education curriculum?
- What role does literacy play in assessment as, for and of learning?
- How can secondary mathematics teachers accommodate literacy in mathematics for English Language Learners and students with language-related learning disabilities?
- What are the current challenges experienced by Ontario high school teachers in regards to literacy and mathematics?

The project also aims to raise awareness of the importance of literacy among secondary mathematics teachers and to promote purposeful teaching of literacy in mathematics classrooms.

1.4 Background of the Researcher

I am currently a second year student in the Master of Teaching program in the Intermediate/Senior division at the Ontario Institute of Studies in Education (OISE), University of Toronto. My teaching subjects are Mathematics and Science-Biology. Prior to coming to OISE, I have had a lot of mathematics tutoring experience with students in grades nine to twelve from public schools. It was through these one-on-one encounters that I first noticed students’ problems with literacy as it played out in mathematics. Most commonly students had trouble solving word problems. Furthermore, it was not always the mathematical concepts and skills that were the hurdle, but reading comprehension and analysis of information. To parallel this experience, I remember my own personal struggles with word problems in grade six as a recent
immigrant to Canada with low English proficiency. I had the mathematical content knowledge but the language barrier prevented me from communicating this knowledge. This is how I first became aware of the use of language and literacy skills in mathematics.

During my first year in the Master of Teaching program, I took a course entitled “Authentic Assessment” where I studied the Ontario Ministry of Education’s assessment policy as outlined in “Growing Success” (Ministry of Education, 2010). Assessment of student’s learning in mathematics (and other subjects) is organized based on four categories: Knowledge and Understanding, Application, Thinking and Communication (Ministry of Education, 2010). It is the communication category that caught my interest in class. If teachers are expected to assess communication in mathematics, than teachers should also teach students the communication skills that they are going to evaluate. From my experience as a student in school, the recollections of my students at tutoring and my observations in two practicum blocks, mathematics teachers do not teach students how to read, write and communicate about math. It is expected that students are taught these skills elsewhere.

My interest in the interdependence between literacy and mathematical content led me to the “discovery” of a number of Ontario Ministry of Education documents. I read Think Literacy Success Grades 7-12, Think Literacy Success: Cross-Curricular Approaches, Grades 7-12, Think Literacy: Mathematics Subject-Specific Examples Grades 7-9 and Supporting Student Success in Literacy. Grades 7-12: Effective Practices of Ontario School Boards. This series of documents helped me better understand the role of literacy in student success from the perspective of policy makers in Ontario. There were also clear expectations from the Ministry of Education that all teachers must teach literacy no matter what their subject area is. The Grades 7-12: Effective Practices of Ontario School Boards document had some examples of teachers
effectively integrating literacy instruction into their pedagogy. However, these were very few in number.

My practicum experience at two urban schools in the Greater Toronto Area, Ontario further ignited my interest in researching literacy and mathematics. In my first year of the Master of Teaching program, I completed four-week practicum blocks in a middle school and high school. I taught grade eight mathematics, grade ten Academic mathematics and grade eleven University/College preparation mathematics courses under the supervision of an associate teacher. Through discussion with my associate teachers, I learnt that they did not consider literacy to be important for success in mathematics. Both teachers did not explicitly incorporate literacy instruction into their mathematics lessons, but at the same time, they evaluated students’ literacy as part of the written responses to mathematics content questions in the communication category of assessments. When prompted about the Ministry of Education documents on literacy, both teachers shrugged them off as being “useless”. The lack of instruction on literacy was completely out of sync with the course assessments in these teacher’s classes.

In my experiences, I have found that a gap exists between Ministry of Education mandates, teacher practices and students’ literacy abilities. Thus, my research project aims to investigate the underlying issues on literacy and mathematics at the high school level with a particular focus on teaching methods, assessment and challenges.

1.5 Overview

The Master of Teaching Research Project (MTRP) is organized into five chapters. Chapter 1 includes the introduction and purpose of the study, the research questions, as well as, how I came to be interested and involved in this topic and study. Chapter 2 contains a review of the literature, which formulates a definition of literacy, advocates for a cross-curricular approach
to teaching literacy, shows why literacy is important in mathematics, describes some strategies for teaching literacy in mathematics and considers the role of literacy in assessment of mathematics. Chapter 3 describes the methods used in this study, introduces the participants and discusses some limitations, as well as, benefits of practitioner research. Chapter 4 presents the main findings of this research project organized around five key themes: secondary mathematics teachers’ definition of literacy; practical strategies for teaching literacy and mathematics content; the role of literacy in assessment of, for and as learning; accommodations for English Language Learners and students with a language-based learning exceptionality; and challenges experienced by secondary mathematics teachers in integrating literacy and mathematics. Finally, Chapter 5 presents researcher’s reflections on the findings; discusses implications for policy, practitioners and teacher educators; considers areas for further study and ends with a brief conclusion.
Chapter 2: LITERATURE REVIEW

2.1 What is literacy?

In today’s world of globalization, multimedia and technology, literacy takes on a new, expanded meaning. This “new” literacy encompasses many different forms of communication: from the traditional book to web pages, television programs, billboard signs, radio podcasts and many more. Literacy is the ability to access these language-based channels of communication and then to critically engage with them. The technical skills of reading and writing are no longer sufficient to be literate in modern society.

In response to rapidly changing technology, globalization and the resulting increase in complexity of texts, the New London Group (1996) introduced the term “multiliteracy” to reflect the rising demands placed on literacy. Two main arguments supported this new concept: “the proliferation of multimodal ways of making meaning where the written word is increasingly part and parcel of visual, audio, and spatial patterns; and the increasing salience of cultural and linguistic diversity characterized by local diversity and global connectedness” (The Multiliteracy Project). Technology introduced new communications media that changed the way we use language in these modes. Furthermore, globalization allowed communication that surpasses linguistic, cultural and national barriers. Literacy education must address these issues and teach students the necessary skills of effective communication in the modern global context (The New London Group, 1996).

An important part of literacy is making meaning of text and the information embedded in it. Today, this interaction requires higher order thinking skills. “Think Literacy Success” defines literacy “as the skills and knowledge in reading, writing, speaking, listening, representing, and viewing that empower learners to make meaningful connections between what they know and
what they need to know. Literacy becomes the ability to understand, think, apply, and communicate effectively to achieve personal and career goals” (English-language Expert Panel on Students at Risk, 2003, p.12). This definition indicates that information is analyzed through application, analysis, synthesis and evaluation, which are all higher order thinking skills from the revised Bloom’s Taxonomy (Anderson and Krathwohl, 2001).

Understanding literacy as the skills and knowledge required to interact with multimodal texts and representations with a particular intention, such as achieving a personal goal, ignores the fundamental sociocultural aspects of literacy that have been well-established in the research field of literacy since the 1980s and 1990s. Literacy is constructed and used in specific social and cultural contexts (Cook-Gumperz, 1986, Scribner and Cole, 1981). Thus, an understanding of literacy also requires an understanding of the specific context in which it is used, as well as, who is using literacy and for what purpose. Furthermore, individuals’ use of literacy is affected by their own “background” including social class, ethnicity, race, gender, and life experiences. Gee (2001) calls each of these social categories a discourse, which he defines as “a socially accepted association among ways of using language, of thinking, and of acting that can be used to identify oneself as a member of a socially meaningful group or ‘social network’” (p.1). Furthermore, Gee distinguishes between primary and secondary discourses. Primary discourses involve the oral use of language with intimate members of a family (or primary socialization group), while secondary require the use of language in social institutions beyond the family (for example, schools). Gee then argues that literacy is specifically the use of language in secondary discourses. A secondary school mathematics classroom is one case of a secondary discourse.
A definition of literacy is important because it affects the way literacy is taught, learned and assessed. Multiple stakeholders, such as practitioners, learners and policy-makers are all affected by the way literacy is defined.

2.2 The need to teach literacy across all content areas in schools

“All teachers are teachers of literacy”

Literacy skills are required for success in all subjects at school. Students communicate and critically analyze information in all disciplines. Thus, it is the responsibility of ALL teachers to teach literacy skills. “Think Literacy Success” (2003) advocates a cross-curricular approach to teaching literacy. The “English-language Expert Panel on Students at Risk (2003) argues that literacy instruction should happen alongside content teaching, which will ultimately improve both content learning and literacy skills.

“Think Literacy Success” (2003) describes the specific role of teachers in regards to teaching literacy in their courses. Teachers should understand the literacy demands of their subject area. They should model and teach reading, writing, and oral language skills that students need to succeed in their course. Finally, teachers should help students to make connections between reading and writing in the subject area, across the curriculum, and to the world beyond the classroom (English-language Expert Panel on Students at Risk, 2003). The document, produced by the Ontario Ministry of Education, sights some research that supports these recommendations and offers suggestions for teaching literacy. For example, Newman and Associates (1996) found that instruction that supports higher order thinking and makes real-world connections develops literacy in adolescents. As well, adolescents working in small groups or partners leads to improvements in vocabulary, fluency and reading comprehension (Taylor
and Nesheim, 2001). Technology can also help students to become competent independent readers if it is motivating for them (Kamil, Intrator, and Kim, 2000).

All teachers have an important role to play in the development of students’ literacy. According to the Ontario Ministry of Education (2004a), teaching literacy is most effective when it is a collaborative undertaking between teachers, departments, administration, the whole school and school board. Other stakeholders, such as family and community, could also become part of the process. Successful literacy strategies have been put in place in a number of schools and school boards across Ontario (Ministry of Education, 2004a). Clarke Road Secondary School at the Thames Valley District School Board is one such exemplary school with an effective literacy development initiative in place. The school has created a “Code of Literacy” based on the belief that all teachers in all subjects are responsible for teaching reading and writing skills to students. All teachers undergo professional development with a focus on reading in the content areas. The program’s success is evident in teachers of science using pre- and post-reading strategies regularly. The departments within the school are strongly encouraged to incorporate the explicit teaching and practice of literacy in their content areas. Finally, a cross-panel professional dialogue on literacy takes place between elementary and secondary schools with a particular focus on literacy in grades seven to nine and the transition from middle school to high school (Ministry of Education, 2004a).

In the research field of literacy education, the need to teach literacy across all disciplines in schools dates back to 1925 and continues to be a dominant theme today. Gray (1925) said that “each teacher who makes readings assignments is responsible for the direction and supervision of the reading and study activities that are involved” (p.71). Similar calls for all teachers, no matter what discipline they teach, to incorporate reading strategies in their instruction (Vacca and
Vacca, 2002) is made today. Entire books have been written encouraging content area educators, such as mathematics secondary school teachers, to teach literacy alongside content knowledge and skills of a specific discipline (for example, Vacca and Vacca, 2002; Alvermann and Phelps, 2002; Brozo and Simpson, 2003; Borasi and Siegel, 2000).

Despite the firm calls of policy makers, researchers and literacy educators to infuse literacy throughout the curriculum, few content area teachers purposefully teach literacy alongside content curriculum in their classrooms (Siebert and Draper, 2008). A number of enduring beliefs about literacy and content teaching is one factor responsible for lack of literacy integration. These beliefs are as follows: it is someone else’s (not content teachers) responsibility to teach reading and writing; content teachers lack the ability and training to teach reading and writing; there is not enough time to teach both literacy and content (Siebert and Draper, 2008). It is important to note that within these beliefs is an implied definition of literacy as reading and writing.

2.3 Why is literacy important in mathematics?

Literacy is undeniably important for success in mathematics. Conceptualizing literacy as a sociocultural practice of interacting with, understanding, negotiating and producing texts [defined broadly as print and nonprint materials (Draper et al., 2005)] for a particular purpose within a specific discourse (Gee, 2001) we can see that mathematics pedagogy is reliant on literacy just as much as other disciplines. Literacy practices in mathematics classrooms include reading the textbook, understanding a word problem, writing a conjecture, using and interpreting manipulatives, drawing graphs, whole-class discussions, student-teacher conversations, and many others (Draper et al., 2005). Most importantly, students who do not engage in these literacy practices will have no way to receive and create the content knowledge of mathematics. Draper
et al. (2005) point out that “students have no access to the content under study unless they are able to successfully negotiate and create the texts used to convey meaning within the discipline” (p.14). Thus, literacy IS a legitimate practice in a mathematics classroom and teachers must instruct their students on the knowledge and skills necessary to consume, create and use texts in mathematics.

Although content-area literacy is not a new field of research, many mathematics researchers, practitioners and educators are still trying to understand and define the place of literacy in the discipline of mathematics. For example, Draper and Siebert (2004) undertook a cooperative inquiry project in an undergraduate, mathematics classroom of pre-service elementary school teachers in order to develop an understanding of literacy and learning in mathematics. Through class observation and extensive discussion of the types of practices that took place in the mathematics classroom, the researchers began to see links between literacy and mathematics learning. They depicted their understanding of how literacy and mathematics are interdependent in the four-component model below.

(Draper and Siebert, 2004, p.952)
Consistent with the sociocultural views of literacy, Draper and Siebert see context as playing an important role in understanding how literacy is utilized in a mathematics classroom. Furthermore, the mathematics discipline itself affects what texts are used and how they are used in the classroom. Mathematics and literacy were viewed to be equally important and interdependent in this model. Students engage in literacy practice in order to gain access and negotiate mathematical content knowledge and in this process, they learn mathematics and literacy side-by-side. Draper and Siebert (2004) conclude that “every mathematics learning event is also a literacy event, and every literacy event in a mathematics classroom is a mathematics learning event” (p. 953).

When thinking about literacy and mathematics, we can also look at specifically the language we use to teach mathematics. A United States Department of Education report (Kamil et al., 2008) recommended that teachers develop student understanding of mathematics language, which is sometimes discipline specific. For example, the mathematical terms, power and radical, have a different meaning in everyday English as oppose to a mathematical meaning (Friedland, McMillen and del Prado Hill, 2011). Consistent with this, Morin and Franks (2010) did a systematic review of the language of elementary school math and concluded that the language can create ambiguity, which can impede the process of learning mathematics. For example, the word “eleven” does not contain any clues to suggest that it is really the sum of ten and one. Another example is the words thirteen and fifteen, which do not follow the general pattern of other “teen” numbers such as fourteen and seventeen. Following the pattern, thirteen and fifteen should be threeteen and fiveteen, respectively (Morin and Franks, 2010). These studies suggest that language is important for learning of mathematics and mathematics teachers should address problematic vocabulary as part of their literacy strategies.
Furthermore, some research has suggested a link between language and mathematics ability levels. Pimperton and Nation (2010) found that children with poor reading comprehension performance also had poor mathematical reasoning ability compared to controls with age-appropriate reading comprehension skills. Donlan (2007) reported that children with specific language impairments also had difficulty in mathematics. Specifically, naming and counting numbers; number processing; working with placeholders in arithmetic; phonological memory and grammar, which related to numerical performance. These studies suggest that a link exists between literacy ability and mathematical performance, highlighting the need to teach mathematics and literacy together.

The research discussed in this section explains how mathematics and literacy are intertwined in the learning of mathematics. Literacy practices provide access to mathematical knowledge, understanding and learning and in this process of learning mathematics, literacy is developed.

2.4 Literacy strategies for mathematics classrooms

A number of resources have been developed by the Ontario Ministry of Education to teach literacy specifically within the discipline of mathematics. The Ministry of Education produced two practical guides to support math teachers: “Think Literacy: Cross-Curricular Approaches, Grades 7-12” (Ministry of Education, 2006) and “Think Literacy: Mathematics Subject-Specific Examples Grades 7-9” (Ministry of Education, 2004b). These documents have many effective instructional strategies to promote literacy development and learn mathematics content. They focus on reading strategies, writing strategies and oral communication. Some examples of reading strategies are creating word walls, using concept circles to extend vocabulary, understanding concepts using the Frayer Model, or learning new vocabulary using
verbal and visual word association. Writing skills can be taught through webbing, concept mapping, or journal writing. Lastly, think/pair/share, timed retell, placemat, and four corners activities all help to improve oral communication for students (Ministry of Education, 2004b, 2006).

Practicing teachers have also written a number of articles published in professional journals about incorporating literacy into a mathematics classroom. Debbie Shults is a veteran Sarasota, Florida teacher, literacy coach and a writer who is establishing a “new literacy” program at her middle school. In her article, she describes practical ways of infusing literacy into the mathematics curriculum. She suggests creating classroom libraries with math books, giving book talks, using pre-reading strategies, and posting word walls. Shults also recommends continuously reading, writing and speaking about math and creating lessons that explicitly teach literacy (Shults, 2008).

Smyth and Waid (2010) state that “content area literacy is a growing trend across the entire secondary school curriculum... [and] ... mathematics teachers are being required to teach reading comprehension in their classrooms (p.113). Some typical activities used to improve reading comprehension are KWL (I Know, I Wonder, I Learned) charts, anticipation guides, think-alouds, and graphic organizers. However, the authors argue that to get the most benefits, students need to read novels and books in a math classroom. “Encouraging students to read in mathematics classrooms, we believe, increases their comprehension of word problems, their mathematical vocabulary, and their critical thinking skills” (Smyth and Waid, 2010, p.114). The authors also give some examples of books and stories that may be used to teach mathematical concepts. For example, Alice in Wonderland can be used to discuss proportions; building a shelter from Hatchet can be tied to a lesson about dimensions and maximum area (Smyth and
However, no suggestions were given for novels that may be incorporated in secondary mathematics classrooms and used to teach senior level mathematics curriculum. Furthermore, the integration of stories and books as a literacy strategy is not explored in depth and it is unclear how these practices are beneficial for students in the learning of mathematics.

Borasi and Siegel (2000) explored the role of reading in mathematics in depth. They conducted a two-year long “Reading to Learn Mathematics” (RLM) project which was comprised of two phases: professional development for secondary mathematics teachers interested in incorporating reading into mathematics and collaborative action research with a subset of these teachers as they integrated reading and mathematics teaching into their classrooms. The authors found that reading had a much more expanded role in mathematics learning than they had envisioned at the beginning of the RLM study. They identify three complementary purposes that reading can have in a mathematics classroom. Firstly, reading can be a means of learning from the text: understanding mathematical processes, using the text as a model, gathering background information about a particular topic, validating students’ results, understanding the big ideas in mathematics. In addition, reading can play an important role in inquiry-based learning in a mathematics classroom. Texts can be a source of ideas, supporting information, prompts for reflection, and a means of facilitating conversation. Lastly, Borasi and Siegel observed reading as a way of negotiating and participating in a classroom community. This can be achieved through collective reading of texts, reading personal journal entries out loud and whole-class discussion of results and hypotheses (Borasi and Siegel, 2000).

Borasi and Siegel also discuss what types of texts were used by secondary mathematics teachers from the RLM project. The authors report a lot of variety in utilized texts: essays, articles, stories, students’ journal entries, questionnaires, posters, final reports, drawn figures,
tables of data, and cartoons. Borasi and Siegel also noticed use of multimedia, such as video, in mathematics classroom and suggested for an expanded definition of “printed matter.” Furthermore, the value of texts depended primarily on how these texts were used, not necessarily on what the text was. Thus, many texts that were not intentionally “mathematical” may still support learning of mathematics (Borasi and Siegel, 2000).

Friedland, McMillen and del Prado Hill (2001) compiled a very helpful annotated bibliography of current articles that describe various literacy strategies in mathematics. The authors defined a literacy strategy as a “an instructional tool that employs any of the language arts – reading, writing, listening or speaking – to facilitate, reinforce or formatively assess students’ comprehension of discipline-specific material (Friedland, McMillen and del Prado Hill, 2001, p. 58). In order to be included in the bibliography, articles had to describe literacy strategies targeted at middle or secondary mathematics classrooms. All of the strategies were coded as vocabulary, comprehension, writing, study skill or a combination of these. Some examples of strategies are journal writing, word walls, visualization prompts for solving a word problem, writing letters based on prompts, student-written mathematical problems, think-alongs in problem solving, and others [for a complete list of strategies, resources, as well as, authors’ explanations, see (Friedland, McMillen and del Prado Hill, 2011)]. What is interesting about all of the articles included in this annotated bibliography is that only two out of a total of twenty-four articles were based on empirical studies. The majority of the articles included anecdotal evidence about effectiveness of the particular strategy/strategies. There is an obvious need for more research on the use and efficacy of literacy strategies in secondary mathematics classrooms.
Despite the best efforts of policy makers, researchers and some practitioners to develop effective teaching strategies of literacy in mathematics, most mathematics secondary school teachers do not regularly integrate literacy and mathematics instruction (D’Arcangelo, 2002; Vacca, 2002; Siebert and Draper, 2008). To better understand why mathematics and other content-area teachers do not utilize the literacy strategies presented in the literature, Siebert and Draper (2008) did a critical content analysis of select research articles, policy documents and methods books on content-area literacy. The authors found that an overwhelming majority of the texts analyzed had “a core problem: they failed to properly acknowledge the influence of the discipline of mathematics on what counts as text, reading, and writing” (Siebert and Draper, 2008, p. 235). These problematic texts had messages that either, neglected, deemphasized, or misrepresented the discipline of mathematics. Siebert and Draper argue that mathematics teachers are not likely to pay attention to these literacy messages because they do not meet their needs in curriculum delivery and appear to be unrealistic for the mathematics classroom.

A more hopeful approach to empowering secondary school mathematics teachers to incorporate literacy into their mathematics instruction is described by Kester Phillips et al. (2010). In a joint project between Niagara University and a high need urban school district, a group of mathematics teachers, literacy coaches and special education teachers worked together to identify strategies of teaching literacy in mathematics. Suggested methods included understanding directional words, small group work, using graphic organizers, understanding varied formats, and problem-solving aloud. Mathematics teachers used these strategies in their classrooms and reported back on their experiences. Overall, at the end of the project, teachers reported an increase in confidence, better mathematics and literacy knowledge and enthusiasm for further professional development. A collaborative approach that values the goals of both
Bridging the literacy – mathematics divide in secondary mathematics classrooms

mathematics educators and literacy coaches seems to be an effective avenue for integrating literacy and mathematics instruction.

The effectiveness of teacher collaboration in learning how to integrate literacy strategies into their teaching is also supported by Thibodeau (2008). This study documented the process and progress made by eight high school teachers from various disciplines, including mathematics, and a literacy specialist in learning specific strategies for integrating literacy and content instruction over a period of one year. At the end of the study, teachers in the collaborative group reported using literacy strategies within content instruction far more than they had previously. In addition, teachers described having “increased knowledge about literacy, increased capacity for the integration of new instructional techniques, increasing feeling of self-efficacy, increased motivation for the changes required by the instructional innovation, and the ability to sustain the effort [for] the changes required over the long-term” (Thibodeau, 2008, p. 59). This study clearly evidences the benefits of integrating literacy and content instruction, as well, the potential success of interdisciplinary educators’ collaboration.

2.5 The role of literacy in assessment of mathematics

In addition to mathematics instruction, secondary school mathematics teachers are also responsible for assessing their students’ knowledge of the curriculum being taught. In Ontario, assessment policy has recently undergone a significant transformation. The new assessment policy is described in the document commonly called “Growing Success” (Ministry of Education, 2010). According to the new policy, the main goal of assessment is student learning and this is achieved through three complementary types of assessments: assessment for learning, assessment as learning and assessment of learning.
Assessment for learning refers to the process of collecting evidence of student learning at the beginning or during a period of instruction in order to better inform what this instruction might look like. Assessment as learning refers students’ self-assessment of their own work – a skill that is developed over time and requires modeling by the teacher. Lastly, assessment of learning is “the assessment that becomes public and results in statements or symbols about how well students are learning. It often contributes to pivotal decisions that will affect students’ futures” (Ministry of Education, 2010, p. 31). This last point made by the Ontario Ministry of Education – assessment of learning (i.e. marks) can affect students’ futures in terms of admission to post-secondary education and/or employment and trade opportunities – makes assessment of all subjects, including mathematics a high stakes endeavour. Thus, it is pivotal to consider what role literacy might play in students’ assessment experiences.

Assessment of mathematics specifically has also changed in Ontario with the revision of the mathematics curriculum and assessment in 2007. Most notably, assessment of secondary school mathematics now requires that a large proportion of assessment comes from the “Communications” category. According to the Ontario Ministry of Education (2007), communication involves “the conveying of meaning through various oral, written, and visual forms (e.g., providing explanations of reasoning or justification of results orally or in writing; communicating mathematical ideas and solutions in writing, using numbers and algebraic symbols, and visually, using pictures, diagrams, charts, tables, graphs, and concrete materials)”. Assessment tools that can be classified as “Communication” are directly related to use of literacy in mathematics.

The recognition of literacy’s place in assessment of mathematics is also mirrored in the research literature. For example, in the previously mentioned study that describes a collaborative
project between a mathematics teacher and a literacy educator working together to examine, discuss and conceptualize the literacy practices that took place in an undergraduate mathematics classroom of elementary school teachers, the following observation was made about literacy and assessment of mathematics:

I [the mathematics teacher] began to wonder for the first time if it was possible for my students to have a solid understanding of mathematics and still be unable to write good explanations. Perhaps writing conceptually oriented explanations and justifications was not a straightforward process that could be equated solely with understanding the mathematics, as I had previously assumed (Draper and Siebert, 2004, p.950).

With the help of the literacy educator, this mathematics teacher began thinking about the literacy demands of his mathematics assessment questions, all of which required open-ended written responses, after his class did poorly on the assessment, although they insisted on knowing the mathematical concepts much better. In another article, Siebert writes that the collaborative project experience made him…

…realize that my assessment of their [students] mathematical understanding could not be separated from their fluency with the texts used to convey that understanding. In other words, every inadequate response to an assessment question could be just as likely due to lack of fluency with mathematical texts as a lack of mathematical understanding (Draper et al., 2005, p.15-16).

This mathematics educator’s experience suggests that assessment of understanding in mathematics is directly related to the student’s ability to express this understanding by creating text, which is literacy. Furthermore, students’ failure to express mathematical knowledge could be equally likely caused by lack of understanding of mathematics or inability to utilize literacy.

The concern for literacy in assessment of mathematics is again brought to the attention of educators by Bosse and Faulconer (2008). Bosse and Faulconer argue that reading and writing are powerful assessment tools in mathematics and these tools are currently not in use in most secondary mathematics classrooms. Furthermore, the content of mathematical assessments also
needs to shift from regurgitation of mathematical facts and algorithms to questions that require students to reflect, make connections, formulate definitions, express new ideas and communicate thinking. Bosse and Faulconer then give specific examples of mathematical assessment tools that would reflect these changes. These are peer evaluation, written reflections on marked tests, portfolios, journal writing, investigate and explain technique, create your own example, definition and theorem altering, and connecting representations (Bosse and Faulconer, 2008). In addition to the mathematical content knowledge, each of these assessment strategies requires reading and comprehension of the question, synthesis and organization of ideas and expressing thinking through a written response. Although the assessment suggestions made by Bosse and Faulconer appear to be valuable and practical, their effectiveness should be tested in empirical studies.

The use of writing in mathematics, suggested by Bosse and Faulconer (2008), is not a novel idea. It has been proposed by mathematics educators since the 1980s (for example, Venne, 1989; Sipka, 1990, Waywood, 1992). However, the need to teach literacy in the context of assessment of mathematics, for example providing assessment for learning opportunities that allow students to use literacy practices in mathematics, has recently come to the forefront of mathematics education.

A discussion of literacy and assessment of mathematics also concerns the distinct situation that English Language Learners and students with language-based Individualized Education Plans (IEPs) find themselves in. The Ontario Ministry of Education (2007) requires that assessment and evaluation tools used by mathematics teachers should "accommodate students with special education needs, consistent with the strategies outlined in their Individual Education Plan and accommodate the needs of students who are learning the language of
instruction (English or French)” (p.24). In addition to the demands of literacy, English Language Learners also have a lower proficiency in the English language, which may affect their performance. Assessments that do not contain any accommodations may not truly reflect ELL’s knowledge and understanding of the mathematics curriculum. Likewise, students who have an exceptionality related to literacy practices, for example dyslexia, will require accommodations in order to learn in the classroom and complete mathematics assessment tasks.

A number of research studies in the United States have found that literacy demands in mathematics can result in lower performance of English Language Learners as compared to students proficient in the English language. Brown (2005) investigated differences in achievement on literacy-based performance assessments (LBPAs) in mathematics between English Language Learners and students proficient in English. The LBPAs are standardized tests, administered in a number of states that ask real-life multi-step mathematics problems that require long solutions supported by explanations of reasoning and thinking. Brown found that LBPAs put ELLs at a considerable disadvantage due to issues of language and this led to ELLs performing significantly lower than their peers fluent in English. Martiniello (2008) reports similar findings in her study of English Language Learner’s and non-ELL’s performance on the Massachusetts Comprehensive Assessment System mathematics test. ELLs had a disproportionate disadvantage answering word problems due to insufficient knowledge of English and difficulties with comprehending the questions (Martiniello, 2008). The two research studies evidence the need to accommodate the literacy demands of mathematics assessment for English Language Learners.
2.6 Summary

This extensive literature review highlights some of the complexities and undeniable interdependence of literacy and mathematics. The literature review begins with a conceptual framework of literacy as a sociocultural practice embedded in particular discourses versus literacy as a discrete skill. The need to teach literacy across all school subject areas, including mathematics, is established.

Mathematics educators need to recognize this relationship between literacy and mathematics and reflect on their practice with this in mind. The research community has recently started to explore and evaluate more strategies for integrating literacy and mathematics instruction. Creating mathematics lessons with explicit literacy practices supports the development of both literacy skills and mathematical content knowledge.

Literacy also plays a role in assessment of mathematics. In order to show their understanding of mathematical content, students rely on literacy to create texts that show this understanding. The literacy demands of learning, teaching and assessing mathematics may place English Language Learners and students with a language-based exceptionality at a disadvantage if their unique needs are not accommodated.

In view of the research literature and Ontario policy documents, this research project aims to understand how currently practicing Ontario high school mathematics teachers conceptualize and integrate literacy into their instruction and assessment of secondary (grades seven to twelve) mathematics courses.
Chapter 3: METHODS

This study explores the intersections of literacy and mathematics in secondary school education. It investigates how Ontario secondary school teachers integrate literacy into instruction and assessment of mathematics, as well as, some of the challenges they experience in doing so. The research was conducted through an in-depth literature review and face-to-face interviews with practicing high school teachers working in the Greater Toronto Area. The data collected represents the views and current practices of Ontario secondary school mathematics teachers. Data was coded according to themes and patterns, which emerged from the interviews and were also prominent in the literature review. The remainder of this chapter describes in the participants’ profiles, data collection and analysis methods, ethical review procedure and some limitations of the study.

3.1 Participants

The primary goal of my research was to understand the current practices, attitudes, and challenges of secondary school mathematics teachers in regards to integration of literacy and mathematics. Thus, all of the selected research participants were teaching mathematics courses in a high school at the time of the interviews or have worked at the secondary (grades nine to twelve) level in the past. The secondary school mathematics teachers had to have some awareness of literacy practices in their own instruction and assessment of mathematics, but they were not required to be experts in this area. Research participants worked in schools that were all located in the Greater Toronto Area, with the majority being public and one private school. Participants were found through a referral process with the help of the research supervisor and a non-practicing secondary school mathematics teacher. Overall, five teachers and one teacher educator were interviewed.
3.2 Background information on research participants

The six research participants who were interviewed for this study are all experienced mathematics educators from the Greater Toronto Area. At the time of interviews, five participants were practicing secondary school mathematics teachers employed by a public school board or a private school. Although these teachers were employed by public and private schools, they all taught according to the mathematics curriculum set by the Ontario Ministry of Education. One participant was a faculty member in a teacher education program with many past years of experience teaching mathematics in a public and private secondary school setting. Every participant is introduced with a pseudonym and a brief profile below.

Laura

Laura has had over seventeen years of teaching experience in both public and private schools. In the past, she has taught mathematics to all grades ranging from grade six to OAC (grade thirteen). She has also taught some numeracy and literacy courses for low functioning students. Laura has had experience teaching English Language Learners with low to high English language proficiencies. In her mathematics classes, she has had students with IEPs requiring language-related accommodations and modifications. Laura’s second teachable subject is English, although she has taught very few English courses in the past.

Patrick

Patrick has been a secondary school teacher for eighteen years during which time he has taught a variety grade nine to twelve mathematics courses. Patrick’s second teachable subject is physical and health education, but in the last few years he has been teaching exclusively mathematics. Patrick teaches at a school with a large recent immigrant population and thus has had a lot of experience teaching English Language Learners.
Brenda

Brenda is employed by a public school board in the Greater Toronto Area and has been teaching high school mathematics for the past twelve years. She has taught many different mathematics courses in grades nine through twelve. Brenda is also the associate curriculum leader of mathematics in her school. Brenda’s second teachable subject is history, although she has not taught many history courses in the past. Brenda has had some experience with students who are English Language Learners or who have a language-related IEP.

Sarah

Sarah has been a secondary school mathematics teacher for twenty two years. She has been teaching at a public school in the Greater Toronto Area for the past eleven years and taught mathematics in a different country prior to that. Sarah is qualified to teach only mathematics. She enjoys teaching enrichment and advanced placement senior mathematics courses. Similarly to other participants, Sarah has had some experience with English Language Learners and students with a language-related IEP.

Lilia

At the time of interview, Lilia was teaching at a public high school in the Greater Toronto Area. She has nineteen years of experience with mathematics education and has taught all high school grade levels. Sarah is the associate curriculum leader of mathematics at her school. Her second teachable subject is computer science. Lilia has had some experience working with English Language Learners and students with language-related learning disabilities throughout her teaching career.

Alexander
Alexander has been a high school mathematics teacher for over twenty-six years. The majority of his teaching career was spent teaching in public schools; however, he has also taught in an independent school. Alexander has taught a large number of high school mathematics courses. Mathematics is his only teachable subject. Beyond his career as a high school teacher, Alexander has also been a teacher educator for the past seven years with a focus on mathematics. Alexander has had limited experience with students who are English Language Learners or who have a language-related IEP.

3.3 Procedure

This research project relies on qualitative data collection methods, which include a review of the literature and informal interviews with practicing teachers. Interviews were conducted in order to understand the current practices of teaching and assessing literacy in a secondary school mathematics courses. Teacher’s views, attitudes and insights were also investigated. Finally, the interview asked about challenges experienced by secondary school mathematics teachers who integrate literacy into their program. The interview data was analyzed and coded according to five key themes. These themes were further interrogated and compared with the literature review. These findings and arguments will be explored in chapters 4 and 5.

Interview questions were developed by the researcher and organized into five categories: participant background, teacher practices, influencing factors, beliefs and values, and next steps (see Appendix B). Interview questions were reviewed and approved by the research supervisor. Potential research participants were found through referral. All were contacted via e-mail with a request for an interview. At the end, six interviews were arranged based on participants’ preference in regards to time and place.
All of the interviews were conducted face-to-face in a school setting. The interviews took place in one of the following places: classroom, mathematics department office, staff room, school library or personal office. The interviewees were provided with a hard copy of the list of questions (included in Appendix B) at the beginning of the interview. Duration of the interviews ranged from thirty minutes to two hours, with the majority being thirty or forty-five minutes. All of the interviews were audio recorded using a digital audio player\(^1\).

Shortly after the last interview was conducted, all of the interviews were transcribed by the researcher. A computer program, called VLC media player, was used to play the interview recordings and slow down the speed of participant’s speech. Verbatim transcriptions were transcribed in Microsoft Office Word. While transcribing, emerging themes and common ideas among the six interviews were noted. The transcriptions were then printed out and hard copies were reviewed multiple times looking for commonalities and differences among participants’ answers. Initial findings were re-visited and new threads identified. Quotes from interviews were re-organized based on five prominent themes and then further summarized using lists and tables. Overall, data analysis revealed five key findings, discussed in Chapter 4.

3.4 Ethical Review Procedure

This research study followed the ethical review approval procedures for the Master of Teaching program at the Ontario Institute for Studies in Education.

Interview participants were given a letter of informed consent (see Appendix A) prior to the interview. The content of the letter was reviewed with each participant and he/she was informed about the purpose of the study, the content of the interview questions and the confidentiality rules to be followed throughout the study. Participants were informed of their

\(^1\) Panasonic SV MP30V - digital player / voice recorder / radio
right to refrain from answering any questions throughout the interview and the option to withdraw from the study at any time prior to its publishing. The procedure was followed exactly as outlined in the letter with no changes made after interviews. Every effort was made to ensure participants’ comfort and willingness to participate in the interview and to have the data included in the research process. Interview participants signed two copies of the letter giving consent to participate in the study. One original copy was retained by the participant and one by the researcher.

After the interviews, audio recordings of interviews were kept on a password-protected hard drive on a personal computer. At the end of the research process, interviews were permanently deleted.

In order to protect the anonymity of the research participants, pseudonyms have been used throughout the research process. Any information compromising the anonymity of participants has been masked or excluded (for example, names of institutions, courses taught, etc.). Furthermore, the research paper underwent a careful review by the research supervisor to ensure complete anonymity of all participants. Participants were informed of this role of the research supervisor and all consented to his review of the data and findings. Careful review of the data, and adherence to ensuring anonymity, meant that participants were well-protected from any kind of harm, whether it be personal or professional.

3.5 Limitations

As proposed in Chapter 1, there are certain limitations to this research study. These limitations include a selective literature review; small sample size; choice of interview questions; possible measurement bias and researcher interpretation in data analysis.
Although every effort has been made to include a comprehensive and thorough literature review (see Chapter 2), the discussed literature remains a selection of total works due to time constraints and scope of this research project. Literature was chosen based on relevance to the topic of literacy in mathematics and currency of the research. The selection is appropriate and presents a well-developed argument for the role of literacy in mathematics education.

The second limitation of the study is the small sample size, which puts into question the generalizability of the data. Nevertheless, all six interview participants were experienced secondary school mathematics educators who currently practice or have taught in the past in public and private high schools in the Greater Toronto Area. The insights of these educators are relevant and valuable sources of data and are appropriate for this research study.

The choice of interview questions could be considered another limitation. The questions were devised and carefully selected in line with the research goals, but still limit the scope of the research. A broader range of issues in literacy and mathematics could have been explored. The “Next Steps” section of interview questions (see Appendix B) gives insight into some of these issues experienced by secondary school mathematics teachers. These topics should be explored in future research studies.

The last limitation of this study to be considered is researcher interpretation. Specifically, the researcher’s position, past experiences, biases and assumptions and their role in data collection and analysis. Prior to commencing this research project, I already had an awareness of literacy in mathematics through my own experience as an English Language Learner and many years of tutoring mathematics to high school students. My experiences led me to question the current practices of mathematics classrooms and particularly the lack of explicit literacy instruction. During practicum blocks in various schools across the Greater Toronto Area, I
approached my associate teachers and other mathematics teachers in regards to literacy in mathematics. The responses I received were very discouraging because they completely neglected the function of literacy in mathematics. There was a stark contrast between my own and my students’ literacy needs in the process of learning mathematics and secondary mathematics teachers’ complete disregard for literacy.

My previous experiences and insights as a mathematics teacher candidate affect the research process and could be considered a limitation. However, being a mathematics educator also adds unique benefits to this research study. Firstly, I am knowledgeable in many of the Ontario Ministry of Education policy and curriculum documents that dictate secondary mathematics teachers’ practice. I also have experience with the general routines of mathematics classrooms in secondary public schools across the Greater Toronto Area. My teaching experience helps me to consider practical aspects of mathematics education as oppose to the theoretical perspectives that research offers. Being a practitioner myself, I can relate to interview participants’ experiences and insights and probe their answers further when needed. Overall, being a mathematics educator adds value to this research study because it bring an insider’s understanding and view of education policy, public schools, and specifically mathematics classrooms.
Chapter 4: FINDINGS

This chapter presents researcher’s findings based on an interpretation of data collected from six face-to-face interviews with practicing secondary school mathematics teachers in the Greater Toronto Area. The interviews explored practical ways of integrating literacy into secondary mathematics instruction and assessment, as well as, issues surrounding literacy in the discipline of mathematics. The findings discuss secondary school mathematics teachers’ view of literacy; instructional methods used to teach literacy in mathematics; the role of literacy in assessment as, for and of learning; literacy-related accommodations required for English Language Learners (ELLs) and students with language-based Individualized Education Plans (IEPs); and challenges experienced by secondary school mathematics teachers when integrating literacy and mathematics.

4.1 Key Findings

Analysis of interview data presented eight general themes in the teachers’ shared experiences and insights about literacy and mathematics. From these themes, five key findings were found. These findings will be explored in detail in this chapter. The key findings of this research study are:

- Secondary school mathematics teachers view literacy primarily as a communication tool.
- Secondary school mathematics teachers use a variety of instructional methods to teach literacy in the context of mathematics.
- Literacy plays a central role in assessment of learning and a lesser role in assessment for and as learning.
• Secondary school mathematics teachers use a number of accommodations for English Language Learners and students with a language-based Individualized Education Plan in relation to literacy in mathematics.

• There are a number of challenges experienced by secondary school mathematics teachers when integrating literacy and mathematics in their classrooms.

Finding #1: Secondary school mathematics teachers view literacy primarily as a communication tool.

When situating literacy in mathematics education, it is important to consider how secondary school mathematics teachers define and view literacy. The definition of literacy determines what kinds of practices are considered to be literacy practices in a mathematics classroom and more importantly, how literacy is taught and whether it is taught at all.

In this research study teachers described literacy as primarily the student’s ability to communicate in writing and speaking in order to convey thoughts and ideas. Teachers also spoke of literacy as the ability to comprehend meaning of written text or spoken word. For example, Brenda2 said,

I would define literacy as, it’s kind of a variation on a concept of communication, it’s the ability to read and understand, to hear and understand, and also to communicate their understanding. I think literacy is more specifically directed toward the written word than the oral communication, but I think it is part of the same package, the ability to make meaning out of someone else and to convey ones’ meaning.

Thinking specifically of a mathematics classroom, teachers also spoke of literacy as the knowledge and proper use of mathematical terms and vocabulary. Mathematics terminology was seen as important for communicating shared meaning among students and the teacher. In

2 All teachers’ names are pseudonyms
addition to proper use of vocabulary, literacy was connected to the ability to organize one’s thinking and express it in a cohesive, easy-to-follow manner. According to Sarah,

> When you talk about literacy in mathematics, in my opinion, it’s talking about communication in mathematics. So using words, writing the process, explaining the steps, and then organizing their work properly. So it’s easy to follow for everybody, the person who is marking or the students that they are working with.

Some of the research participants made a distinction between literacy and mathematical literacy. Laura saw mathematics “as a way to communicate outside of language” and Lilia said, “it [literacy] can also mean that in terms of mathematical literacy, being able to interpret and solve problems and communicate the solution to a problem in a cohesive way.” Similarly, Patrick divided literacy into two distinct groups.

> One group would be the way English people would think of literacy – how to write, communicate verbally and on the uses of the English language. There is also mathematical literacy, which is how we write down mathematics and how we communicate actual mathematical thought, which is often very different than how we would communicate thoughts in English. That is how I separate those two.

The separation of literacy and mathematical literacy is noteworthy. First of all, it highlights the division of disciplines and especially secondary school subjects: English, mathematics, history, etc. into distinct categories, each with their own legitimate practices and conventions. Secondly, it evidences secondary mathematics’ teachers’ narrow view of literacy as the ability to communicate through writing or speaking. Some of the participants did not even mention reading as a literacy practice. Lastly, the distinction between literacy and mathematical literacy places literacy outside the discipline of mathematics. The participating mathematics teachers are essentially saying that there is a mathematical literacy that is unique to the discipline of mathematics and the “English-type of literacy” is different and beyond their field.
Viewing literacy as a communication tool also disregards the sociocultural aspects of literacy and discourses that affect the literacy practice (Gee, 2001). Secondary school mathematics teachers in this study viewed literacy as an isolated practice devoid of outside influences. There is no awareness of how student identity, classroom discourses and teacher’s own beliefs affect literacy practice. Participants’ definitions of literacy most closely resemble the Ontario Ministry of Education’s views on literacy as “the skills and knowledge in reading, writing, speaking, listening, representing and viewing” (English-language Expert Panel on Students at Risk, 2003, p.12).

Overall, secondary school mathematics teachers viewed literacy a communication tool for conveying and extracting meaning from written or spoken word. In the context of mathematics, literacy also included proper use of mathematical terminology. Furthermore, some teachers highlighted mathematical literacy as a separate “branch” of literacy.

**Finding #2: Secondary school mathematics teachers use a variety of instructional methods to teach literacy in the context of mathematics.**

Secondary school mathematics teachers in this research study discussed a number of pedagogical methods that they use in their classrooms in order to integrate literacy into mathematics instruction. All interview participants stressed the importance of student-made glossary and/or word walls for new mathematics vocabulary. It was imperative that students write down their own definitions of terms using sentences, diagrams, examples or other ways that will help them to understand the new words. Laura explains,

> The back of their notes is a glossary where they write their own glossary. I give them all the terms at the beginning of the year they can organize it, set it up however they want. They have to have an example or a diagram or something and then the glossary. They go to make that. They make it from their own learning, they can also go and research it.
Similarly, Brenda spends class time on defining new mathematics terms. Brenda asks students to put mathematical terms into non-mathematical contexts in order to better understand and remember the meaning of new vocabulary.

I am trying to always get kids to define a word with using their own understanding of that word, well have you ever heard that word before, so everything from what is the domain of the function, well what is the domain, what is a function? To things like the words factor, what does that mean to say driving a car a lot is a factor of green house emission, what is the concept of that word? So for me actually taking time away from instructional moments and turning them into kind of literacy moments to get kids to focus on the meaning of the words, to me that very important, because in the future when there isn’t a teacher in the front of the room, guiding their understanding, they have to have the skill that says well I don’t know what this words is in this context, but maybe there is another context that makes sense to me.

From the interviews, it was also evident that secondary school mathematics teachers are very purposeful and deliberate about the language they use during lectures. Repeating important mathematical terms multiple times was thought to be helpful for students to remember new vocabulary. For example, Patrick said, “What I do is, I really stress the vocabulary in math. I repeat the words about 15 times, so if they are dealing with proportion, I will say the word ‘proportion’ about a thousand times. Any words like quadratics, factoring, trinomial are capitalized in large letters; repeated many times.” Using appropriate language was also thought to be important for students’ comprehension of oral explanation and lectures. Lilia explains,

even when I am speaking I have to ensure that the language that I use is appropriate because a lot of the kids really get caught up in the language and some teachers don’t realize that the students don’t understand what they are actually saying when they are writing on the boards. I really have to ensure that you speak in a very conscientious way about the language.

Teaching new mathematical vocabulary, getting students to make their own personalized dictionaries, and being aware of teacher’s use of language was one literacy approach that mathematics teachers found beneficial in their classroom. Furthermore, these teachers required
that students *use* this vocabulary correctly during class discussions and student group work. The ability to discuss mathematics using proper vocabulary and the ability to follow the discussion was seen as a valuable literacy skill by all teachers interviewed. In Laura’s classroom, the students often took on a teacher role and instructed their classmates about a particular topic.

They understand that the expectation is that they will be the teachers…And that is a very key literacy goal for me is that they not only communicate to themselves and to me but to each other. And that they explain mathematics. So in their small groupings they do that all the time but they actually have to take a role to explain to other people and that is a VERY important literacy skill [pause] to do feedback so that they listen and then they respond and then they ask questions and come back and present. So they do what is way more traditional teaching than I ever do.

Other secondary school mathematics teachers praised students for proper use of vocabulary and listened to student discussions about mathematics in small groups.

Interestingly, all teachers interviewed viewed the ability to communicate well and explain one’s thinking as evidence of true understanding and mastery of mathematics concepts and skills taught. Brenda points out, “their ability to explain the concept and I tell them to explain it like you are explaining it to your younger brother. And it tells me their ability to communicate in that way demonstrates their true understanding of the concept.” Likewise, Sarah believes “if they can communicate mathematics then they can do mathematics. I think communicating is even harder than just doing it. So when I get them communicating that, I am really happy.” However, Draper and Siebert (2004) argued that it is important to distinguish between mathematical content knowledge and literacy practice, because understanding of mathematics does not automatically translate into an ability to express this understanding through creation of a print or non-print text. Making the distinction between mathematics and literacy is important since some students fail to express their mathematics thinking because they cannot meet the literacy demands and not because they do not understand the mathematics.
The last instructional strategy for teaching literacy in a mathematics classroom emphasized by all teachers interviewed was explicit instruction on how to solve mathematics word problems. The approach to teaching word problems was similar among all of the mathematics teachers and included reading comprehension, identifying key information and problem-solving using a specific mathematical tool (such as modeling with an equation, using a formula, using an algorithm and others). For example, Lilia reflects on her recent teaching experience,

I find that especially now with the word problem section that we are working on, the students always find this the most difficult part of the course. And so we try to do similarities and differences to other word problems and specifically go through…I teach a word problem as taking language and putting into mathematical form. So taking the actual words and putting it into a new language which is math. And so we pick apart sentences of the word problems, we see that some of them didn’t understand what the sum of the squares meant for instance. So they didn’t understand that you are taking those two things and adding their squares.

It was a common experience for all secondary school mathematics teachers interviewed to deal with students who are struggling with understanding and solving word problems. An important question to ask here is why do some students struggle so much with mathematics word problems? Looking at a broader definition of literacy as a practice affected by students’ discourses can give some insight. If students background knowledge, life experiences and other discourses are not reflected in the context of a mathematics word problem, than it might be difficult for students to relate and understand the question. For example, if a particular trigonometry word problem is presenting a scenario with bearings and sailing, students who have no knowledge of sailing terminology would find it difficult to interpret the given information and solve the problem even if they understand all of the trigonometry principles. However, more research is needed before any conclusions can be made.
In addition to the instructional methods for integration of literacy into mathematics utilized by all secondary school teachers interviewed, there were other methods utilized by only some of the research participants. Laura and Sarah both used writing for understanding in order to teach literacy in the context of a mathematics classroom. Students in Laura’s classroom often do a “stop and write” after an experiment, for homework or during classroom time in order to record what had happened and particularly what they had learned. Sarah utilized writing in a different way and asked her students to do reflective writing on tests. Students were required to find their mistakes, correct them, and write about the process of doing so and what they had learnt as a result. This is a literacy strategy that was highly recommended by Bosse and Faulconer (2008). Both mathematics teachers stressed the importance of the process of writing as a tool to teach literacy and knowledge and understanding of mathematical content. Writing was also used by other mathematics teachers as an instructional strategy for incorporating literacy into their pedagogy. Writing involved answering probing questions in class or in the homework in paragraph form. In addition, Sarah sometimes asked for written explanations to accompany mathematical solutions with a thorough explanation of how the solution was obtained.

Writing in mathematics is a well-established literacy strategy that has been proposed by mathematics educators since the 1980’s (Venne, 1989; Sipka, 1990; Waywood, 1992 and others). However, the secondary mathematics teachers in this study do not address the issue of supporting and developing student’s writing, especially for students who may be poor writers. The participating high school teachers spoke of using and expecting writing in their mathematics classes, but they have not explained how they teach writing.

Lastly, some teachers interviewed spoke of using cross-curricular connections in mathematics or putting mathematics into context in order to teach literacy. Cross-curricular
connections were often made to history of mathematics or use of mathematics in the real world. Brenda says, “I am always trying to relate math to everything else, so it is not just this isolated little package of x’s and plus signs and that sort of thing. And I think literacy is a part of that. Like that the ability to decipher information and to answer question, whether that question is a math question or not, is an important skill in every class.” However, it was unclear what specific strategies Brenda uses to teach literacy in mathematics using cross-curricular connections.

Alexander’s cross-curricular strategies were directly related to literacy and mathematics. In his teaching, Alexander often integrated mathematical questions and exercises with the reading of newspaper articles, novels and even fieldtrips. For example, when teaching a grade twelve Calculus course, Alexander’s class read the book, The Story of e, and learnt calculus concepts and rules from supplemental notes created by Alexander. Thus, the history of calculus and the number, e, was integrated with the teaching and learning of the calculus curriculum. When his class went on a mathematics fieldtrip, they travelled to different parts of Toronto and in small groups, read and followed instructions from a booklet. This booklet told students to walk, observe mathematics in the real world and apply their mathematical knowledge in order to calculate, model or describe mathematics they were seeing. Thus, students’ literacy would be developed when reading, understanding the instructions and writing answers down. Alexander commented that

We rob kids of a lot of things. They learn math in a vacuum. No history. Often times no applications. You know …it’s just they learn all these rules and manipulating things and they have no clue about, you know, the beauty. About how it’s applicable. And the history of the subject and all that.

Integrating literacy, history and real-world applications into mathematics instruction allowed Alexander to teach in a more holistic manner and to engage students in a meaningful way.
When discussing instructional methods for teaching literacy, it also became evident that all of the teachers interviewed created their own resources. None of the mathematics teachers utilized the Ontario Ministry of Education’s “Think Literacy: Cross-Curricular Approaches, Grades 7-12” (Ministry of Education, 2006) or “Think Literacy: Mathematics Subject-Specific Examples Grades 7-9” (Ministry of Education, 2004b). This suggests that the Ministry of Education resources do not meet the needs of mathematics teachers in regards to integrating literacy and mathematics. Taking into account the review of literature and policy documents done by Siebert and Draper (2008), it is likely that the Ministry of Education documents have messages that neglect, deemphasize or misrepresent the discipline of mathematics. Furthermore, more resources need to be created that will be useful to secondary school mathematics teachers in addressing literacy issues in their classrooms. The annotated bibliography of current articles describing various literacy strategies in mathematics (Friedland, McMillen and del Prado Hill, 2011) is a good first step towards creating such resources.

Overall, it was found that secondary school mathematics teachers utilize a variety of strategies for integrating literacy into mathematics instruction. A summary list of these strategies is presented below.

**Instructional methods used by secondary school mathematics teachers for integrating literacy and mathematics content teaching:**

Strategies used by *all* interview participants:

1. Student-made glossary and/or word walls for new vocabulary
2. Whole class and student group discussions
3. Focus on word problems – reading comprehension, identifying key information, mathematical problem-solving (modeling with an equation, using a formula, an algorithm, etc.)

Strategies used by some interview participants:

4. Writing for understanding
5. Cross-curricular connections in mathematics

Finding #3: Literacy plays a central role in assessment of learning and a lesser role in assessment for and as learning.

Assessment of Learning

Interviews with secondary school mathematics teachers revealed that literacy plays a central role in summative evaluations (assessment of learning) of mathematics. The majority of mathematics teachers discussed assessment of “Communication” questions on tests in relation to the role of literacy in assessment. The Ontario Ministry of Education requires that teachers assess students’ learning in four different categories of knowledge and skills: Knowledge and Understanding, Application, Thinking and Communication (Ministry of Education, 2007). In accordance with this, secondary school mathematics teachers include questions on tests that specifically assess communication. Literacy in terms of the ability to organize one’s ideas, to explain concepts fully and to write coherent answers in full sentences were considered to be important for student success on these communication questions. To this end, Sarah says,

The mathematics curriculum requires students to be able to communicate mathematical knowledge and communication is part of literacy. So it is vital part of the assessment and therefore some questions on the test can be of the type that the students explain where things are coming from, you know, why something is true, or be able to compare certain characteristics of the functions. So for that they have to be able to communicate using mathematical terms.
In addition to tests, there were other forms of assessment of learning utilized by some secondary school mathematics teachers that relied on literacy. Laura talked about signature assessments which involved collection of data and reporting back on the learning from the activity. Students had to explain in writing what they did, what results they got and what they learnt in the process. Literacy was a central component of such assessments. Other mathematics teachers also gave assignments with questions or tasks that required students to write about their knowledge and understanding of a particular topic or concept in mathematics. Brenda gives an example,

I just had my grade nine academic, they handed in a project to me where I gave them the answer in advance, the answer is seventeen or whatever, and I said “but your job is to explain to me how you get that answer and you have to explain it step by step and that’s what I am looking for.” So it’s not just on tests or quizzes, it’s on a bunch of different things throughout the year.

From the interviews, it was also evident that communication questions on assessments were often connected to higher-order thinking such as explaining, hypothesizing, comparing, connecting and synthesizing mathematical concepts and ideas. When asked about communication and higher order thinking on the signature assessments, Laura replied,

but I think that once you engage language in it, it has to do that. Because sometimes it’s harder to do that in math. The higher order part comes from the extrapolating beyond the example. So they have to lift it up, to draw general principles, to write down what they’ve learnt, as soon as they are going to do that they are going to take it out of the specific. Which is often times in math we are sort of focused on the specifics unless we do a proof which we don’t do anymore.

Overall, secondary school mathematics teachers thought literacy was important for assessment of learning, particularly on communication questions on tests, which required students to create written text in order to express their knowledge of and thinking about mathematics content.
Assessment for Learning

Literacy played a minor role in assessment for learning according to the secondary school mathematics teachers in this research study. A few interview participants spoke about the role of literacy in peer edit assessments. Laura found the peer assessment and feedback strategy very effective.

As I said they do peer review of each other’s work and sometimes they do it by writing right on it, sometimes they do it with post in notes. If a student thinks if their work is so at a high enough level. If they think they are just going to make small changes than they will ask, they usually write on the top “please, only write in post it notes” But other times the kids write right on the work…And the thing about peer-review is that it makes your own work stronger… I went and looked and four other peoples, now I have more ideas to come back to take to my own stuff. And because I work with a lot of stuff that’s individual, like that data is going to be mine, it’s not going to look the same as yours.

When reading and giving written feedback to other students on their work (assessment for learning), students were believed to improve their literacy and mathematical content knowledge.

Literacy also played a role in assessment for learning when teachers listened and assessed students’ ability to communicate in a small group or whole class discussion. Teachers assessed proper use of mathematics vocabulary and identified any misconceptions evident in student’s communication. Lastly, some teachers also gave students practice “communication questions” that would likely appear on a test, quiz or assignment. Students could then practice putting their ideas down on paper and answering in paragraph form – the literacy component. Lilia explains,

I have also done certain just evaluations where I asked them specific question like for instance one of the questions in the beginning of the year I asked was “Why do you need to have a common denominator when you are adding and subtracting fractions?” and you wouldn’t believe me but it is was very hard for them to communicate why they need a common denominator in fractions. So they need to practice this to be literate in math, they need to understand the concepts as well and being able to communicate why certain things are the way they are.
Overall, secondary school mathematics teachers utilized few assessment for learning strategies that involved literacy.

**Assessment as learning**

When discussing the role of literacy in assessment, secondary school mathematics teachers rarely talked about literacy in assessment as learning. Only Sarah discussed an assessment as learning strategy where literacy plays a central role. For all of her tests, Sarah requires that students do reflective writing which identifies their mistakes on the test, corrects the errors made, and includes a written explanation of why the student made a mistake. Literacy is central in the process of reading the test over again and writing reflections.

I let them a chance to improve the test marks by doing reflective writing on the test. So when they got test back, they could earn extra marks for writing, first of all redoing the questions that they did wrong and they had to do all of those questions, not just pick two or three. They had to do all of them and then they had to write what was the mistake, why they made the mistake, what they learned from that experience from doing the questions. And when I was reading this text for an incredible amount of time, it takes much longer marking the tests. But it gives me the vision, how they were thinking during the test and some students wrote a very good explanation of their mistakes and when I was reading this, I was sure that that was the best thing they could’ve ever done… When those students did this reflective writing, I did not take up the questions, they had to figure it out themselves. They went back to their notes, the textbook, and they were still thinking about those questions. And I think that is much better experience for them because first of all they learn the topic, second of all they had to write about it, so that is also reinforcing the terms, reinforcing the usage of language. And I think it was a great experience for everybody and they really enjoyed marking it.

Similarly, Sarah often gives students a second chance at improving their writing on assignments. Sarah says, “I sometimes even get the assignment back to them and say “You have to redo it. You have to explain it better. You have to justify your answers properly using definitions, using quotes, using theorems, and you know it is like in English when they write an essay, they always do like one or two or three tries before they actually submit the essay for marking. You know, in
math, kind of similar thing.” As a result of re-evaluating and re-doing their work students have a chance to improve literacy and learn the mathematical content. Sarah’s assessment as learning strategies offer a great opportunity to teach literacy to students in a mathematics classroom.

Looking at assessment overall, literacy seemed to play a central role in assessment of learning and a much lesser role in assessment for and as learning practices. This is a very problematic trend because it indicates that students do not have the chance to learn and practice tasks that involve literacy in mathematics, such as the “communication” questions on test, before they are evaluated. There is little formative feedback given to students identifying areas for improvement and specific strategies on how to develop literacy and improve performance. With no assessment as learning practices targeted at literacy in mathematics, students receive no instruction on how to edit their work and the process of becoming independent learners is impeded. Requiring students to complete literacy-demanding tasks in mathematics but not giving them the tools to do so is dangerous, especially since final assessments can have tremendous effects on students’ futures (Ministry of Education, 2010). Lastly, the purpose of assessment, according to the Ontario Ministry of Education (2010), is student learning. Student learning cannot happen if secondary school mathematics teachers do not provide opportunities for students to learn, practice and self-assess their literacy abilities in the mathematics classroom.

**Finding #4: Secondary school mathematics teachers use a number of accommodations for English Language Learners and students with a language-based Individualized Education Plan in relation to literacy in mathematics.**

The secondary school mathematics teachers interviewed discussed a number of accommodations that they made in relation to literacy and mathematics for English Language
Learners (ELLs) and students with a language-based Individualized Education Plan (IEP). These accommodations are explored in the next few pages.

**Accommodations for English Language Learners**

All of the mathematics teachers interviewed emphasized the use of graphical and visual representations of mathematics to supplement the use of English language. Graphical and visual representations could be used by the teacher and by the student. Interview participants thought that allowing ELLs to represent their thinking and knowledge in visual ways was a good accommodation for assessments. Teachers also commented that this kind of accommodation for ELLs was beneficial to the whole class.

Vocabulary lists and focusing on meaning of words was another strategy for accommodating ELLs, as well as, other students in the class. Patrick said, “I actually treat all of them as English language learners. I really do. Even though I know that some of them are like “alright, move on”. I just feel like there is so many gaps.” Lilia also elaborates on the importance of building vocabulary as a literacy strategy in mathematics for ELLs:

So in ESL classes, the focus is on building basic vocabulary. So having them write all words, having them write every definition, having them really explain what the equation is about. That is a big part of teaching in those classes. It goes much smaller, you go with the curriculum much slower. But you have to put emphasis on vocabulary because if they do not understand what they are doing they will not be able to do it. So in ESL classes, it is a big difference because you really have to focus on what every single term means and sometimes even drawing a diagram and labeling beneath the diagram in English words makes a difference. The kids need to have their own dictionary with the pictures and that is reinforcing the words they are studying and the classes that they study.

Another part of the vocabulary strategy was highlighting important key words on assessments for English Language Learners, as well, as other students. Highlighting focused ELLs’ attention on the key words, which helped them to understand the questions being asked. Brenda explains,
I also have highlighted the tests or quizzes for them. So I will have already highlighted the most important phrases to try to narrow their focus on just the key words. Because you will notice that sometimes I will give them a test or quiz and I will see them translating the unnecessary words. And I will wonder, “Oh, they are not even sure which words are important.” So sometimes just by highlighting important stuff, they will know “do not translate that; that is just extraneous information.”

The last literacy accommodation strategy for ELLs discussed by many of the mathematics teachers was pairing up an ELL with an older student who speaks the same language. This type of student partnership was thought to benefit both students. It provided an ELL with support, mentorship and help adjusting to the new school, while the other student developed leadership and mentoring experience. Laura said that this was a school-wide program at her school, while other mathematics teachers arranged the partnerships themselves.

Peer tutoring is also something we use in our school a lot. And we think it works really, really well. So, giving kids a peer tutor who speaks the same language as they do but an older student who then works with them in the afternoon. And that is...we use that a lot and it does work very, very well.

Some other strategies for accommodating ELLs with literacy in mathematics included photocopying notes of other students, use of electronic translators, and pairing up an ELL with another student mentor in the same mathematics class. These strategies were not common among all of the mathematics teachers interviewed.

Summary of accommodations made by secondary school mathematics teachers in literacy and mathematics for English Language Learners:

Strategies used by all interview participants:

1. Using graphical and visual representations
2. Focus on teaching new vocabulary
3. Highlighting important key words on assessments
4. Pairing up an ELL with an older student who speaks the same language(s)
Other strategies used by some interview participants:

5. Photocopying notes of other students
6. Students using electronic translators
7. Pairing up an ELL with another student mentor in the same mathematics class

The effectiveness of accommodations for English Language Learners as described by secondary school teachers interviewed remains to be proven through empirical research, although preliminary evidence from this study suggests that they are effective in meeting the needs of ELLs in secondary school mathematics classrooms.

**Accommodations for students with a language-based IEP**

Secondary school mathematics teachers interviewed had a lot less accommodations available for students with a language-based IEP compared to accommodations available to ELLs. Overall, mathematics teachers had less experience and a lower comfort level with accommodating literacy demands of mathematics for students with special needs.

One common accommodation for students with a language-based IEP specified by secondary school mathematics teachers was the use of technology. The actual technologies discussed varied from Smart board lesson recordings, voice recording on an iPad, Kurzweil text to speech reading and writing assistive technology and various graphing software. One common trend among these different technologies is more visual representations and less written language. Laura describes how she accommodated one particular student in her class in relation to literacy in mathematics:

I have a student, last year actually I forgot because I just saw her in the hall, who has all kinds of language issues in her IEP and we worked really, really hard to graphically distribute everything or describe everything in graphs of in symbols. Worked really, really hard. But she had a computer so it was helpful because we could work and save what we were doing and then go back and have a… So she wouldn’t have to do as much writing. She also dictated a lot,
like audio recorded a bunch on on...we had an iPad Pilot, and that was really helpful because you can do a voice recording on an iPad really, really quickly. And she could also write on the whiteboard on the iPad so that was really helpful to do during assessments. Do I think it might have been a little harder for her? Yes, I think in the long run, she got better because of it. Because she was able to have more skills outside of her area of weakness. She capitalized on her strengths and pushed them even more and “oh that meant I can also do this, I could make a graph all the time.

The second most common accommodation for students with a language-related IEP according to the teachers interviewed was more one-on-one tutoring time with these students. One-on-one time was provided by either the mathematics teacher or a special education teacher in the school. The one-on-one tutoring most often focused on comprehension of text – figuring out important information, reading out loud with emphasis on key words, probing questions for the student, or teaching missing prior knowledge. Lilia talks about accommodating literacy in mathematics to students with a language-based IEP:

Not specifically when you are doing lessons but when they are working individually, they go to a specialized classroom where they have more one on one attention and language can be, you can really understand better the misconceptions they have on a one on one basis. With them I find more than with the ESL kids, you have more one on one contact with those kids. And they tend to be the ones who come in for the extra help a lot of times. They need that extra one on one to help them through the language. I just had one of the students here who was an IEP, he really struggles with the language. Another girl who really struggles and she even just reading the problem for her, if you read it to her that helps. Being able to read to them, emphasize certain words that they don’t quite catch as being important and emphasizing the question also helps.

Overall, the secondary school mathematics teachers interviewed predominantly used technology and one-on-one tutoring sessions in order to accommodate literacy in mathematics for students with an IEP for issues with language. Teachers were also less comfortable and knowledgeable about accommodating this group of students in regards to literacy and mathematics.
Finding #5: There are a number of challenges experienced by secondary school mathematics teachers when integrating literacy and mathematics in their classrooms.

All secondary school teachers interviewed experienced challenges when integrating literacy into the instruction and assessment of mathematics in their classroom. Three challenges were common among the secondary mathematics teachers in this study. Firstly, teachers found it difficult to deal with expectations from students, parents and other teachers that mathematics is a discipline of numbers and symbols with little to no language use. Brenda explains,

> You know a lot of them approach math as numbers and symbols, you do something to them and then you get numbers and symbols and there’s always a big struggles in terms of helping students to decipher what a paragraph says and turning those words into math is a huge issue in a math classroom, it’s something where a lot of students tell me very directly “miss I’m good at math, but I can’t do word problems”, which to me is an interesting thing to say, because a word problem, it’s like there’s this definition where math shouldn’t have words in it, you know? It’s almost like some students believe that, and I think that maybe some teachers in grade 6, 7, and 8 maybe believe that as well, that if it’s math, it doesn’t have words in it.

Brenda also mentions the middle school (grades 6, 7 and 8) mathematics education as one of the factors contributing to lack of preparation for high school mathematics in terms of literacy. Likewise, Patrick strongly believes that some middle school teachers do not prepare students well for the demands and expectations of high school mathematics.

> Students have a lot of difficulty talking the talk, learning the vocabulary of mathematics and throwing that on to paper. I would say that it is a weakness, but a lot of these weaknesses I also thing come from or based upon more or less where these kids come from – middle schools and the way it works in the middle schools. Middle schools present the high school experience with a lot of issues and problem. I think that one thing I struggle in as a teacher, particularly as I teach grade nine applied, is the kids come with zero skills. Not zero, but minimal skills. Point being is, these skills can be so weak in both areas. They can be weak in mathematics and they can be very weak in English written skills, as well... In addition to that, I got to say for the record, the very fact that kids can’t fail middle school (they get promoted or transferred), affects my experiences teaching literacy in my mathematics class.
Lack of learning skills seems to be a second challenge for secondary school mathematics teachers in terms of literacy and mathematics. Laura explains what type of learning skills students require in order to do well in her literacy-integrated mathematics classroom.

…the learning skills, probably as you can imagine, requires much greater amount of learning, you have to have all your stuff all the time, you have to you know, manage much more executive functioning stuff. Absolutely, you have to. Because it’s pulling on all those different resources. You know you don’t have your calculator now, you are behind now because you need your calculator now to do the picture, you need the picture, you need your graph, you need your data. You know, you got to manage all your stuff, you got to have it all in one place, you have to do a review.

Thus, it appears that in addition to literacy, learning skills have a role to play in student experience of learning mathematics and are a challenging area for mathematics teachers.

The third challenge in integrating literacy and mathematics discussed by most secondary school mathematics teachers in this study is lack of time in the classroom and the need to cover curriculum set out by the Ontario Ministry of Education. Brenda says,

I think the big challenge is just the curriculum is really unforgivable, especially at the grade 9 level and the EQAO. There is just not breathing room as it is… And I think that is the biggest challenge and it is challenge for a lot of reasons but especially when you are trying to teach literacy. You are trying to get students to be like holistic learners and it’s incredibly challenging to fit it in and still cover the curriculum.

The time constraints and need to teach the entire curriculum were echoed by other secondary school teachers. Similarly, Siebert and Draper (2008) reported that mathematics teachers often identify lack of time as a factor preventing them from integrating literacy into their instruction.

On the contrary, Alexander had very differing views about the lack of time that many mathematics teachers speak about.

Any teacher who says there is no time for this has a fundamental flaw in their thinking. They are looking at the textbook and they are saying I will do section 1.1 today and I do 1.2 tomorrow and so on. And there is just nothing in the Growing Success document, there is nothing posted in the Ministry and there is...
no Ministry of Education that has ever said that is how you teach math. This is what people have brought to the table with them because quite frankly that is how they learned it and they figure it is the best way and what they don’t realize is that may be it worked for them but there are a lot of students that it doesn’t work for. It just bored the heck out of kids. When they are on the treadmill of going through these sections and it’s the same every day - take up the homework, do a lesson, do some work. That’s just so boring for kids. But if you mix things up a little bit and you did things in a bit of a different way, it makes it more interesting for kids. You are still covering what you still have to cover. You are still covering the curriculum through these media clips or the math trails. You are still doing the math but it’s just done in a holistic way. In a way where you are connecting things. The ironic thing is that the curriculum documents do talk about that. About connecting topics to each other. So when you are doing percents, connect another topic to that. They actually spell that out in the document. But a lot of teachers never read the first 20 pages of the document. They just immediately go to the content… and then they look at this, the math trail or using technology, it needs to be embedded in what they are doing.

Even though Alexander thought that the Ontario Ministry of Education curriculum could be easily covered in the allotted time, he did find some other challenges in integrating literacy and mathematics. Alexander’s primary challenge was unmotivated students and low student engagement.

Overall, secondary school mathematics teachers found a number of challenges when integrating literacy and mathematics in instruction and assessment. The main challenges experienced by most teachers were:

- Expectations from students, parents and other teachers that mathematics should only contain numbers and symbols with little to no language use
- Some students coming to high school with poor learning skills
- Lack of time and the need to cover the entire curriculum set out by the Ontario Ministry of Education
4.2 Summary of findings and connections to research questions

This research study looked at how secondary school mathematics teachers in Ontario view literacy and how they integrate literacy into instruction and assessment of mathematics. The research study also investigated some challenges experienced by teachers in doing so. The three main research questions were:

- What are the practical ways of teaching literacy in grade nine to twelve mathematics classes in adherence with the Ontario Ministry of Education curriculum?
- What role does literacy play in assessment as, for and of learning?
- How can secondary mathematics teachers accommodate literacy in mathematics for English Language Learners and students with language-related learning disabilities?
- What are the current challenges experienced by Ontario high school teachers in regards to literacy and mathematics?

Data collected from interviews was organized into five key themes, which provide answers to the main research questions. Secondary mathematics teachers’ views and definitions of literacy were investigated first. It was found that the mathematics teachers generally had a very narrow definition of literacy as the ability to communicate orally or in writing and to comprehend written or oral text. In view of this definition, secondary mathematics teachers reported a number of literacy strategies that they incorporate into their teaching of mathematics curriculum. The strategies used by all teachers were student-made glossary and/or word walls; whole class and student group discussions and explicit instruction on solving word problems. Some mathematics teachers also used writing for understanding and cross-curricular connections.
to teach literacy in the context of mathematics. Overall, it was found that mathematics teachers do not explicitly teach literacy in mathematics courses, although literacy is required in order for students to learn, negotiate and show understanding of mathematics (Draper and Siebert, 2004).

In regards to assessment, literacy was found to play a central role in assessment of learning exercises, especially on test questions that were categorized as “Communication,” and a much lesser role in assessment as and for learning. Although teachers recognized the need for literacy in completing summative evaluation tasks, most teachers did not help students to develop literacy through assessment for or as learning exercises. Thus, the core purpose of assessment – student learning – was not met.

Secondary school mathematics teachers reported using a number of strategies to accommodate English Language Learners in regards to literacy. Strategies used by all teachers included graphical/visual representations, focusing on vocabulary, highlighting important key words on assessments, and pairing up an ELL with an older students who speaks the same language. Other strategies used by only some of the interview participants were photocopying notes of other students; allowing use of electronic translators; and pairing up an ELL with a student mentor from the same class. The effectiveness of these accommodation strategies and the specific needs of English Language Learners in regards to literacy in mathematics should be further investigated in future studies.

Mathematics teachers also highlighted the need to accommodate students with a language-based IEP. In general, teachers were less comfortable and knowledgeable about accommodating this group of students. Some of the reported strategies were more one-on-one tutoring time and various uses of technology: visual representations, voice recording, text to speech reading and assistance with writing. Accommodating and supporting the literacy needs of
students with a language-related learning disability in mathematics remains an area not well understood by mathematics teachers and should be researched in future studies.

Lastly, mathematics teachers commented on a number of challenges they experience when integrating literacy into mathematics instruction and assessment. These were expectations from students, parents and other teachers that mathematics should only contain numbers and symbols with little to no language use; poor learning skills of some students; and lack of time combined with the need to cover curriculum set out by the Ontario Ministry of Education. Resolving these challenges would support mathematics teachers’ objectives of integrating literacy into mathematics instruction and assessment.
Chapter 5: DISCUSSION

In this final chapter, researcher’s reflections, implications of findings, areas for future study and concluding remarks are presented. The chapter begins with researcher’s reflections about the main findings of this research project. Implications for policy development, practitioners and teacher education programs are then discussed, followed by suggested areas for future research. Finally, the chapter ends with a brief summary and conclusions.

5.1 Reflections

Expanding the definition of literacy in mathematics

The definition of literacy established in the literature review (see section 2.1) differs significantly from how secondary mathematics teachers in this research study define literacy. Mathematics teachers viewed literacy primarily as a communication tool and the ability to read and comprehend written or spoken text. Literacy educators and researchers understand literacy in relation to the particular context, intent and discourses. Thus, the questions of who is using literacy, where it is being used and for what purpose matter in terms of understanding and defining literacy practices. Secondary mathematics teachers also need to ask these questions when thinking about the literacy instruction in their classrooms.

The discourses of mathematics classrooms are also important for understanding literacy in mathematics. What are the discourses of students who make up mathematics classes? What is the discourse of the teacher who is creating the instructional program? What are the discourses of mathematics classrooms in general and how does this support (or impede) literacy practices in mathematics? Finally, what are the discourses of mathematics as a discipline? Draper and Siebert (2004) argue that the discipline of mathematics should dictate what counts as literacy practices in mathematics. Traditional print materials are not the dominant form of text for communicating
and understanding ideas in mathematics. Thus, an expanded definition of literacy that includes both print and non-print materials and the discourses of mathematics teachers, students and the discipline itself is necessary.

An understanding of what literacy is and how it is used in the mathematics classroom needs to go beyond the research field to include all stakeholders in secondary mathematics education. For example, one of the challenges reported by secondary mathematics teachers interviewed was the expectation that students, parents and teachers have about mathematics as a discipline of numbers and symbols with little language use. These kinds of misrepresentations of mathematics can be corrected with an expanded view of literacy embraced by students, parents, teachers and others. Recognition of the role of literacy in mathematics also needs to happen at the level of policy makers. Literacy in mathematics should be interwoven throughout the mathematics curriculum. This would address the issue of lack of time to include literacy in mathematics instruction described by teachers in this research study. After all, without literacy students do not have access to mathematical content (Draper et al., 2005).

Resources for literacy practices in secondary school mathematics

Secondary school mathematics teachers in this research study described a number of practical ways to integrate literacy into mathematics instruction. Other strategies for teaching literacy in mathematics were also explored in the literature review (see section 2.4). The annotated bibliography of current research articles describing literacy strategies in mathematics (Friedland, McMillen and del Prado Hill, 2011) was particularly useful. Furthermore, the mathematics teachers interviewed did not utilize the current Ontario Ministry of Education resources for teaching literacy in mathematics. This suggests the need for new resources that describe effective and relevant literacy strategies for secondary mathematics classrooms. In order
to create such resources, it is important to consider not only what strategies are currently used by secondary mathematics teachers, but also how and why particular literacy practices work.

Lastly, secondary mathematics teachers should be supported in their efforts to teach literacy. Literacy initiatives should be maintained in and across departments and schools. The Ontario Ministry of Education (2004a) highlights some examples of schools that have successful literacy programs in place. Collaboration between literacy educators and mathematics teachers has also proven to be very effective (Thibodeau, 2007 and Kester Phillips et al., 2010).

**Literacy in assessment for and as learning of mathematics**

Secondary school mathematics teachers in this study mainly considered literacy in assessment of learning. The majority of teachers talked about the literacy demands of assessment of learning questions on tests that fall under the “Communications” category. Few teachers considered the role of literacy in assessment for learning and assessment as learning. As mentioned before, this is a very concerning finding because it means that students do not have the chance to learn literacy in mathematics prior to final assessments. Students should be given the opportunity to develop literacy in mathematics under the guidance of a teacher and with descriptive feedback given. Furthermore, developing students’ self-assessment capacity in relation to literacy and mathematics is beneficial for their long-term learning.

**Literacy-related accommodations in mathematics**

Secondary school mathematics teachers reported making a number of accommodations for English Language Learners and students with a language-based Individualized Education Plan in relation to literacy and mathematics. Accommodations were done for both instruction and assessment of mathematics. Generally, teachers were more proficient with accommodating ELLs and wished to know more about accommodating students with language learning disabilities.
Special attention should be paid to accommodating assessment tasks for both of these groups of students. As presented in the literature review, some studies have found that ELLs perform poorly on mathematics assessments that are reliant on literacy (Brown, 2005 and Martiniello, 2008). Thus, special attention should be paid to how ELLs and students with language learning disabilities are assessed in mathematics. This requires more research and guidance from the Ontario Ministry of Education.

5.2 Implications

Implications for policy development

Policy developers play an influential role in shaping teaching practices and educational experiences of students. Incorporating literacy into mathematics instruction and assessment policy documents is an important step towards effective mathematics teaching. It would be useful to include literacy and mathematics expectations into existing curriculum and assessment documents, which are already in use by teachers. Mathematics policy and curricula should draw upon current research in literacy and mathematics that highlights the interconnectedness of these two domains commonly viewed as being totally separate. Research suggests that literacy instruction in mathematics should be explicit and purposeful. Assessment for and as learning literacy strategies can also support student learning in mathematics classrooms. While literacy has always been an “invisible” part of mathematics, it is time to bring literacy in mathematics to the forefront through changes in policy that will transform how students learn and are assessed in mathematics classrooms.

Implications for practitioners

The findings of this research study have great implications for current secondary mathematics teachers. Mainly, mathematics teachers need to understand what literacy is,
according to the expanded definition presented here, and then to consider how literacy affects the learning of mathematics for students. Recognizing the prominent role of literacy in mathematics also means that teachers need to have explicit literacy instruction in addition to mathematics content. Comprehensive, research-based resources of effective literacy strategies specific to mathematics would be useful in helping teachers meet students’ literacy needs in mathematics. Based on the research literature review and interview data from this research project, such resources have not been compiled. The secondary mathematics teachers interviewed relied on their own resources and strategies for integrating literacy and mathematics. This resulted in inconsistency of strategies used among the pool of teachers interviewed. This also implies that students in different classrooms across the province of Ontario are experiencing different standards of mathematics education.

Secondary mathematics teachers also need to evaluate their assessment tasks in terms of the literacy requirements needed to complete those tasks. The literacy components should be taught explicitly with opportunities for guided practice and other assessment for learning practices, such as descriptive feedback. For example, answers to the “Communications” category test questions that many teachers mentioned, should be modelled by the teacher and practiced by students before appearing on a test. Furthermore, to further develop students’ literacy and mathematics, teachers should focus on assessment as learning strategies that will allow students to become independent learners. Special consideration and accommodations should also be given to English Language Learners and students with language-related learning disabilities in terms of instruction and assessment of mathematics.

Secondary mathematics teachers should not be left unsupported in their attempts to integrate literacy into current practice. Professional development opportunities that discuss what
literacy is, how it is connected to mathematics and how to teach literacy within the context of mathematics should be offered. The issues of literacy in assessment and accommodating English Language Learners and students with a language learning disability should be addressed in professional development as well. Furthermore, Thibodeau (2008) and Kester Phillips et al. (2010) found that a collaborative approach between teachers from various disciplines and literacy experts was successful in altering teachers’ practices to include more explicit literacy instruction, changing teachers’ beliefs about literacy in relation to their disciplines and increasing confidence about teaching literacy. Thus, I believe that teacher collaboration in and between schools should be encouraged and supported by literacy experts.

**Implications for teacher education**

Pre-service mathematics teachers also need to understand the role of literacy in mathematics. Teacher educators can provide necessary guidance in defining literacy and learning how to teach and assess literacy in the context of mathematics. Collaboration between a mathematics educator and a literacy expert, as seen in the research project by Draper and Siebert (2004), could be a mutually beneficial partnership.

**5.3 Areas for further study**

The interplay of literacy and mathematics in secondary mathematics classrooms remains an area not thoroughly researched and understood by educators and researchers alike. Although this research project has shed some light onto the place of literacy in secondary mathematics classrooms, there are many areas for further study. Participating secondary mathematics teachers shared some instructional methods for teaching literacy and mathematics content. However, effectiveness of these literacy strategies, as well as, additional methods should be investigated. Furthermore, researchers can also look at factors that support or impede students’ learning of
literacy in mathematics classrooms. For example, how do teacher-student interactions shape literacy strategies and their uses? What established norms, practices and discourses of a mathematics classroom support learning of literacy? What are students’ views on literacy in mathematics? How can technology support or impede the learning of literacy in mathematics?

Research articles about literacy and assessment of mathematics are just beginning to emerge in the research field. This is an important area of study with great implications for student learning. As mathematics teachers negotiate and implement new assessment policies from “Growing Success” (Ministry of Education, 2010), they should be mindful of the role of literacy in assessment of mathematics.

Lastly, two particular groups of students deserve special attention in the research of literacy and mathematics: English Language Learners and students with language-related learning disabilities. These students have special needs and require accommodations for literacy in mathematics. Research should focus on identifying their educational needs, particular strategies to help learn literacy and mathematics content and assessment accommodations.

5.4 Conclusion

The process and main findings of this research project contribute to a growing body of research in the area of literacy and mathematics. The views and practices of secondary mathematics teachers interviewed are representative of an average high school mathematics teacher in Ontario. Although there are limitations to this study, findings regarding teachers’ definitions of literacy, instructional methods, assessment strategies and accommodations for English Language Learners and students with a language-related learning exceptionality raise a number of concerns for the current place of literacy in mathematics classrooms. Mainly, the strategies used to teach literacy in mathematics are limited and their effectiveness is unknown,
Assessment of learning tasks most often used to assess mathematics rely on literacy to represent and communicate mathematical content. Despite this, few assessment for and as learning opportunities are given to students in order to develop literacy in the context of mathematics. Furthermore, English Language Learners and students with language-related Individualized Education Plans require special accommodations in regards to literacy and mathematics. Secondary mathematics teachers had difficulties accommodating special education students and expressed a desire to learn more about teaching this particular group of students. In light of these findings, implications for policy development, practitioners and teacher educators were presented in the hopes that more attention is paid to the role of literacy in mathematics. As a mathematics teacher candidate, I strongly believe in the need to explicitly teach literacy in mathematics and the benefits for student learning that this will have in mathematics classrooms and beyond.
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APPENDICES

Appendix A: Letter of Consent for Interview

Date: __________________

Dear __________________,

I am a graduate student at OISE, University of Toronto, and am currently enrolled as a Master of Teaching candidate. I am studying literacy in secondary school mathematics for the purposes of investigating an educational topic as a major assignment for our program. I think that your knowledge and experience will provide insights into this topic.

I am writing a report on this study as a requirement of the Master of Teaching Program. My course instructor who is providing support for the process this year is Dr. Patrick Finnessy. My research supervisor is Dr. Rob Simon. The purpose of this requirement is to allow us to become familiar with a variety of ways to do research. My data collection consists of a 45 minute interview that will be tape-recorded. I would be grateful if you would allow me to interview you at a place and time convenient to you. I can conduct the interview at your office or workplace, in a public place, or anywhere else that you might prefer.

The contents of this interview will be used for my assignment, which will include a final paper, as well as informal presentations to my classmates and/or potentially at a conference or publication. I will not use your name or anything else that might identify you in my written work, oral presentations, or publications. This information remains confidential. The only people who will have access to my assignment work will be my research supervisor and my course instructor. You are free to change your mind at any time, and to withdraw even after you have consented to participate. You may decline to answer any specific questions. I will destroy the tape recording after the paper has been presented and/or published which may take up to five years after the data has been collected. There are no known risks or benefits to you for assisting in the project, and I will share with you a copy of my notes to ensure accuracy.

Please sign the attached form, if you agree to be interviewed. The second copy is for your records. Thank you very much for your help.

Yours sincerely,

Oleksandra Moldovan.

Researcher name: Oleksandra Moldovan
Email: sasha.moldovan@utoronto.ca
Phone number: 647-746-7371
Consent Form

I acknowledge that the topic of this interview has been explained to me and that any questions that I have asked have been answered to my satisfaction. I understand that I can withdraw at any time without penalty.

I have read the letter provided to me by Oleksandra Moldovan (name of researcher) and agree to participate in an interview for the purposes described.

Signature: ________________________________

Name (printed): __________________________

Date: ____________________
Appendix B: Interview Questions

Thank you very much for agreeing to let me interview you for my Master of Teaching Research Project.

I am interested in how Ontario high school math teachers, such as yourself, integrate literacy into their instruction and assessment of secondary mathematics courses.

Section 1: Participant Background Information

1. a) What grades and mathematics courses are you currently teaching and have taught in the past?  
   b) How many years have you been teaching for?  
   c) How would you define literacy?  
   d) What has been your own personal experience studying literacy and mathematics at the high school level?

Section 2: Teacher Practices (What? How?)

2. a) Can you please tell me about the experiences you’ve had teaching literacy in your mathematics classroom?  
   b) What specific instructional methods do you use to teach literacy in a mathematics classroom?

3. What kinds of resources have you used to inform your teaching of literacy in mathematics?

4. Thinking specifically of assessment, where and how do students use literacy to demonstrate their understanding of mathematics?

5. What has been your experience (if any) with literacy and English Language Learners in your mathematics classroom?

6. What has been your experience (if any) with teaching students with a literacy or language-related Individualized Education Plans (IEP) in the mathematics classroom?

7. Are there any additional anecdotes or comments that can help to further my understanding of literacy in your mathematics classroom?
Section 3: Influencing Factors (Who?)

8. What challenges, if any, have you experienced in teaching literacy in a mathematics classroom?

9. What kind of feedback have you had from students, parents, colleagues, administration or others regarding your practice of teaching literacy in a mathematics classroom?

Section 4: Beliefs and Values (Why?)

10. How does literacy contribute to student success in your math classes?

11. In your opinion, how does literacy relate to student’s overall success in secondary school?

12. What do you think is the importance of literacy in relation to participating in today’s society?

Section 5: Next Steps (What next?)

13. What would you still like to learn about integrating literacy and mathematics?

Thank you very much for your time. Your insight and experience has been invaluable. My e-mail and phone number is listed on the letter of consent, if you would like to get in contact with me. If you think of any additional comments about literacy in mathematics in the future, I would love to hear from you by e-mail or phone. Thank you!